CHAPTER ONE

INTRODUCTION

1.1 Background

Servomotors are specially designed motors to be used in control applications and robotics. They are used for precise position and speed control at high torques. It consists of a suitable motor, position sensor and a sophisticated controller. There are hundreds of servomotors applications we see in our daily life. The main reason behind using a servo is that it provides angular precision, i.e. it will only rotate as much we want and then stop and wait for next signal to take further action.

Servomotor is used widely in CNC machine. CNC machine (Computer Numerical Control) is one in which the functions and motions of a machine tool are controlled by means of a prepared program containing coded alphanumeric data. CNC can control the motions of the work piece or tool.

1.2 Problem Statement

In CNC machine operation the accurate speed and position using tool is very important for any application. Precious and accurate control of position and speed is achieved with aid of control system to solve the problem of inaccurate positioning.

1.3 Objective

The main objectives of this study are:

- Understanding the servomotor.
- To understanding the working principles of CNC machine.
- Operation and control of servomotor using in CNC machine.

1.4 Methodology

To achieve thesis objectives the following methodology is used.

- Investigation CNC machine operation and components.
- Study the servomotor system used in CNC machine.
- Investigates the control of servomotor using in CNC machine.

1.5 Project Layout

In this project there are five chapters have been presented as follows.

Chapter One: This chapter present full background about the project.

Chapter Two: This chapter rich by the information about CNC machines these information are knowledgeable because they are consist of their types, operation and application.

Chapter Three: This chapter present the electrical motors that used in the CNC machines addition to that it also show the control of these motors (in this study we will take the control of servo motor).

Chapter Four: This chapter show the simulation that lead to how the control of the servo motor been done.

Chapter Five: Conclusion and recommendations.

CHAPTER TWO

COMPUTER NUMERCAL CONTROL SYSTEM

2.1 Introduction

A CNC is a self-contained NC system for a single machine tool which uses a dedicated mini compute, controlled be the instructions stored in its memory, to perform all the basic numerical control functions.

Other definition it's "The numerical control system where a dedicated, stored program computer is used to perform some or all the basic numerical control function in accordance with control programs stored in read I write memory or Random Access Memory (RAM of the computer).

2.2 CNC system components

The main components of CNC system are:

1. Software.
2. Machine Control Unit (MCU).
3. Machine tools (MT).

2.2.1 Software

The programs or set of instructions, language, punched cards, magnetic tape, punched paper tape and other such information processing items are referred to as software.

This software controls the sequence of movement of an NC. That is why these NCs are called sometimes software controlled machine, and the skill required in producing a part by NC lies entirely in the programming. The study of the Numerical Control is, therefore largely the study of information programming routines.

2.2.2 Machine Control Unit (MCU)

Every NC machine tool has a main unit which is known as MCU, consist of some electronic circuitry (Hardware) that reads the NC program, interprets it and conversely translate it for mechanical action of the machine tool.

The MCU may be of three types:

i. Housed MCU

This MCU itself, may be mounted on the machine tool or may be build in the casing of the machine.

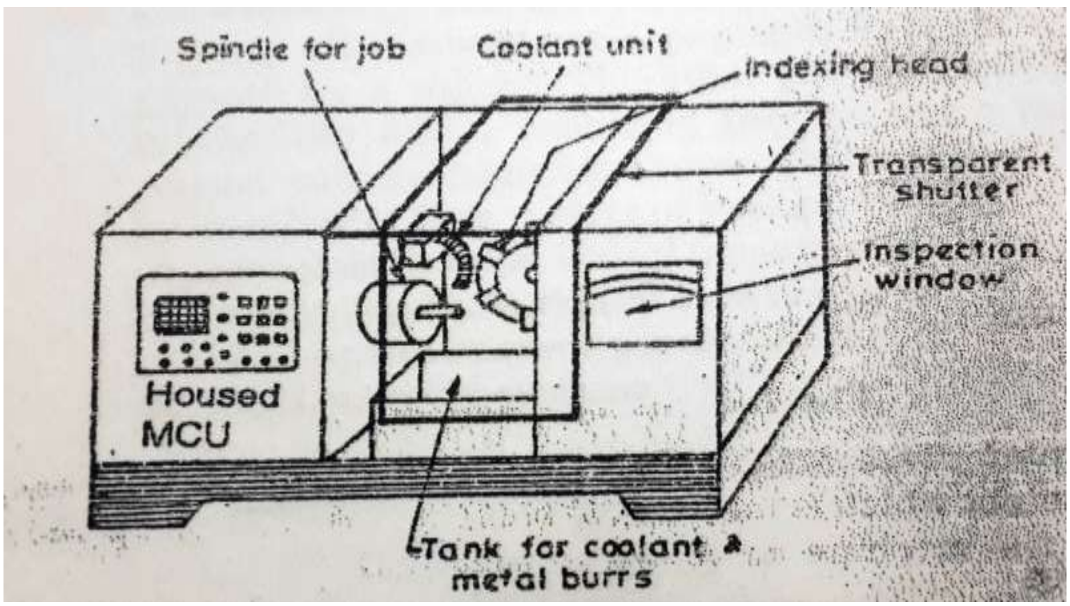

Fig. 2.1: Housed MCU

ii. Swing around MCU

This MCU is directly mounted on the machine which can “swing around” it and can be adjusted as per requirement of the operator’s position. This arrangement provide large working space around the machine.

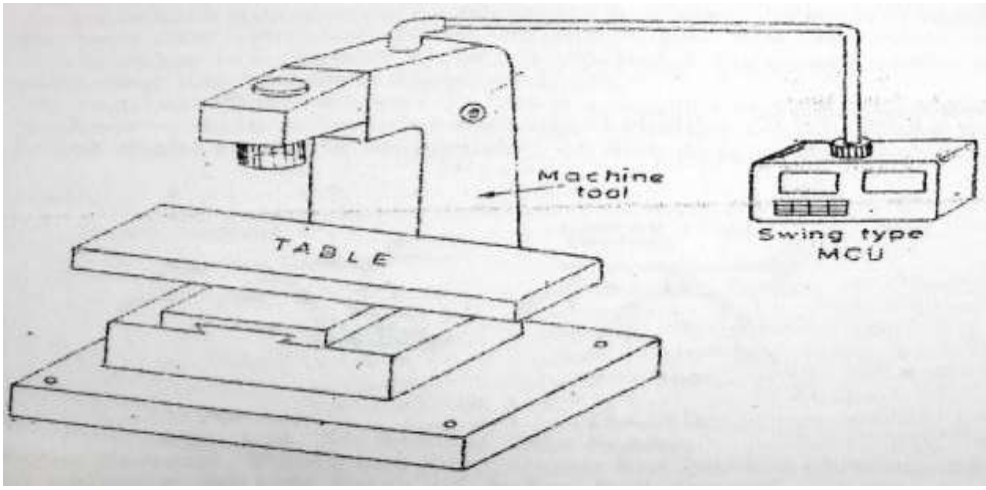

Fig.2.2: Swing around

iii. Stand-alone MCU

This MCU is enclosed in a separate cabinet which is installed at some remote or some place near to the machine.

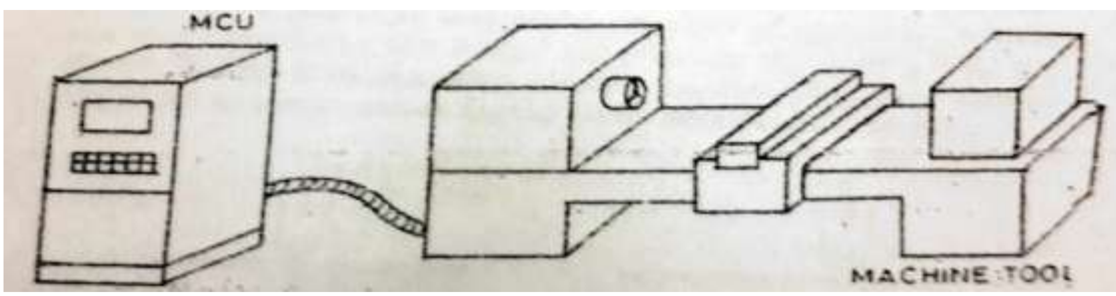

Fig.2.3: Stand-alone MCU

2.2.2.1 Sub unit of MCU

A typical MCU may consist of the following units:

i. Input/Reader unit.
ii. Data buffer (Memory).
iii. Processor.
iv. Output channel and actuators.
v. Control panel.
vi. Feedback channel and transducers.

i. Input/Reader unit

Input or Reader unit consist of electro-mechanical devices used to collect the input media (punched tape, cards, magnetic tape and disk), drive it through the system under reading head, interpret the coded information and collect it again for reuse. Spool are used for punched tape, magnetic tape and a bin for cards.

ii. Data buffer (Memory)

A complete block of information, consisting of words, is read from tape and stored into temporary memory called buffer. One logical block may contain one complete set or instruction words in sequence, like locating the tool on job and then doing the operation at that position. Different words are stored in specific memory location.

The function of this memory is to keep and storing the next block of words when the machine is doing processing of previous block.

iii. Processor

Previously the processor or controller used vacuum tubes, then transistors and later on now, IC (Integrated Circuits) technology. These were “hard-wired” that means they had always a fixed number of features, functions and operation. So later on software based processer such as a mini computer, were used giving the concept of CNC. But still the conventional hard-wire processor used, have the advantage of using lesser storage space, fast working and less expenditure. The function of it is to co-ordinate and control the function of other units, by giving ready signals to them at appropriate point of time.

iv. Output channel and actuators

The data stored in the buffer is converted into actuation signal and supplied through output channel in the form of pulses. These channel are nothing but pins on IC or wires from the processor. The pulse signal is of very small voltage and current, which is amplified by electronic or electro-magnetic amplifier or thyristors. These amplifiers along with some circuitry, which drive (actuate) the servo/split field/stepper motors or some hydraulic/pneumatic power unit for positioning and contouring the machine tool, are known as Actuators.

v. Control panel

The control panel permit the operator to interfere the machine operation manually. It may be an emergency stopping machine's movement or Manual Data Input (MDI) instead of tape or to change the tool speed. These interrupts given, override the data been fed by tape. It may also have the switches, indicators and dials for providing information to the operators.

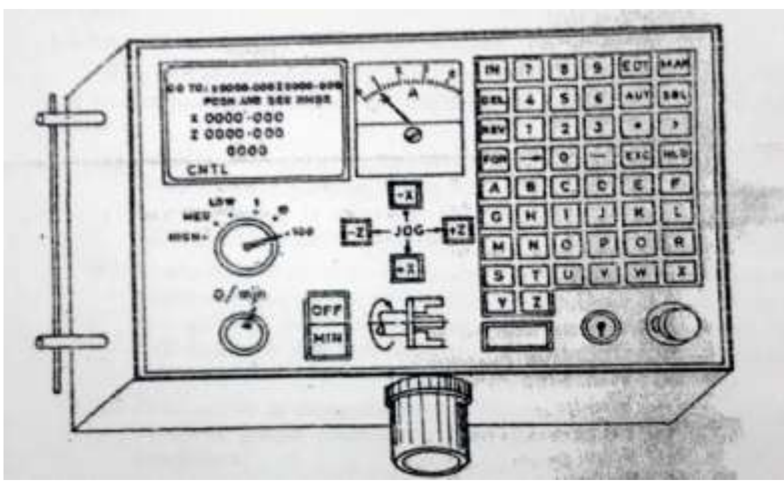

Fig.2.4: Control panel

vi. Feedback channel and Transducers

To check whether the operations are done in the way we want to, the feedback (mostly position and velocity) is send through feedback channels. Position and displacement measuring devices are known as Transducers. They may be resistive, inductive, capacitive or optical devices. Sensors may be digital for sensing "ON" or "OFF" or Analog for position of job or tool.

2.2.3 Machine tool (MT)

It is the main component of the system, which executes the operation. It may consist of a simple drilling machine to the most flexible machining centers.

The control unit and panel of a CNC is somewhat similar to the NC controls. Only difference being that works in On-line mode and NC in batch processing mode. It can be mounted or stand-alone type as in NCs. The day by day lowering of the prices of the computers has increased the demand of CNCs. The latest CNC units have more memory, processing speed and more intelligence built into the computer. A typical CNC may need only the drawing specification of a part to be manufactured and the computer automatically generates the part program for the loaded part.

CNC offer flexibility and computational capacity along with options. New, system options can be incorporated into the CNC controller simply by the reprogramming the unit and due to this characteristics of the CNC machine, it is also termed as “soft-wire” NC machine.

2.3 Function of the CNC machine

The principle function of CNC are:

- 2.3.1 Machine tool control.
- 2.3.2 In-process compensation.
- 2.3.3 Improved programming and operating features.
- 2.3.4 Diagnostics.

2.3.1 Machine tool control

It is the prime function of the CNC system to control the machine tool. This involves conversion of the part program instruction into machine tool motions through the computer interface and servo system.

2.3.2 In-process compensation

It is closely related function to machine tool control. This involves the dynamic correction of the machine for change and error which occur during processing.

The main options as follows:

- Adjustment for error sensed by in-process inspection probes and gauges.
- Recompution of axis positions when an inspection probes is used to locate a datum reference on a work part.
- Offset adjustment of tool radius and length.
- Adaptive control adjustment to speed and /or feed.
- Computation of predicted tool life and selection of alternative tooling when indicated.

2.3.3 Improved programming and operating features

The soft-wire control has permitted the introduction of many convenient programming and operating features. The main features are as follows:

- Editing of part program at the machine.
- Graphic display of the tool path to verify the tape.
- Prevision of various types of interpolation, circular, parabolic, and cubic.
- Support of old customary units and new metric units.
- Use of specially written subroutines.
- Manual Data Input (MDI).
- Local storage of more than single part program.

2.3.4 Diagnostics

Presently, CNC machines are equipped with a diagnostics capability to assist in maintaining and repairing the system. The main features of these provision are as follows:

- To minimization of downtime.
- To give warning about imminent failurity of a certain component.
- To contain a certain amount of redundancy of components which are considered unreliable.

When any of these unreliable components fails, the diagnostics subsystem would automatically disconnect the faulty component from the system and active the redundant component in place of faulty one. Thus repairs could be accomplished without any breaks in normal operation of the CNC machine. After getting repairs the redundant components comes out from the system automatically so that newly installed component can perform its function.

2.4 Classification of CNC machine

To achieve the maximum benefit from the use of NC system, it is necessary to realize that it is not "just another metal cutting technique ". It is a technique of discipline which is applied correctly before installing a NC machine.

According to meet different requirement within the cost constraints.These machines are broadly classified as the following:

2.4.1 Feedback Control: open loop and closed loop.

2.4.2 Motion Control: positional, paraxial, continuous path.

2.4.3 Circuit Technology: analog, digital.

2.4.1 Classification based on feedback control

In the CNC machines, it is feasible from control point of view to relate the behaviour of a particular variable (velocity/position of the tool or job) to one corresponding variable.

To control position/velocity of a machine slide, a group of electro-mechanical, pneumatic or hydraulic component are used which are collectively known as **Servo mechanism**. The output from the data handling equipment (one data for each axis of machine motion) is passed through separate channel to servo system which in turn drive the machine slides. This servo system based on feedback control, can be approached in three ways:

i. Open loop control system

A control system, in which the final output value is not directly measured and check against the desired value, is known as Open loop control system. The final value may be however, be implicitly known providing there has been no mal function.

In open loop control system, there is no feedback device to measure the actual position of tool slide or work table. Hence it cannot be compared and verified with the positional value given in command.

So, the system appear to be 'open' in the sense that it does not respond depending upon the position value of tool/work. The indication, that the desired location had reached, is the end of input command signal to servo motor, the open loop control as shown blew.

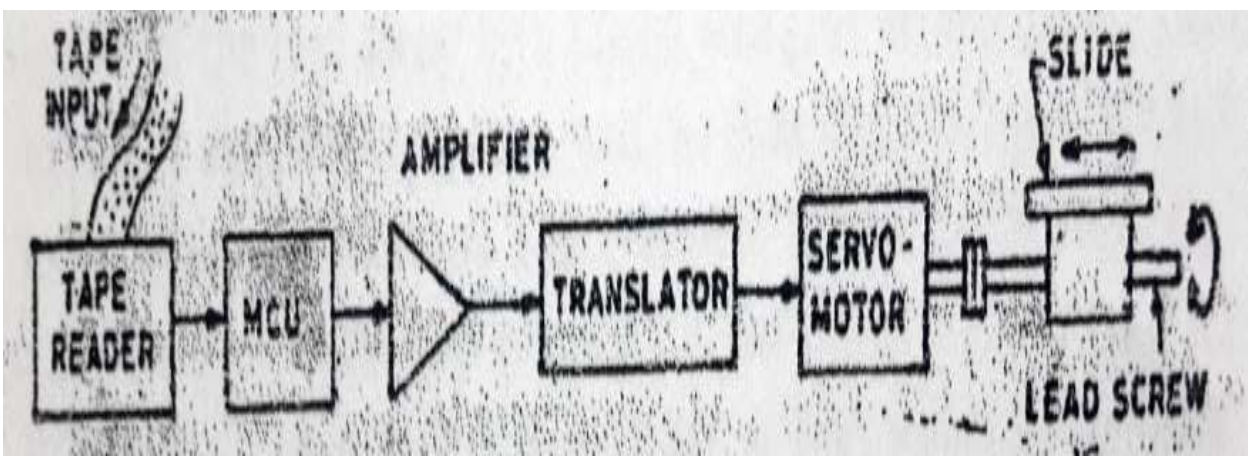

Fig.2.5: open loop control system

ii. Closed loop control system

A control system in which the displacement of machine slide is balanced input signals mainly by signals received from feedback devices, is known as closed loop control system. In this system there are two input signals to drive a motor. One is command signal due to which the servo motor is driven. As soon as the displacement take place, another signal is generated by the position sensor known as transducer, to known that whether the position has been achieved or not. This actual position signal is fed to the comparator device known as **Differential Analyzer** which compare it with the command signal and produce an electrical signal proportional to the difference between the two. This signal is fed to servo motor through an amplifier to move the machine slide in a direction to reduce the difference. This loop is followed again and again till the difference between the two signal (input and feedback) becomes to zero and the machine slide comes to reset in the correct position. This mechanism takes care of the inertia effects of machine slide.

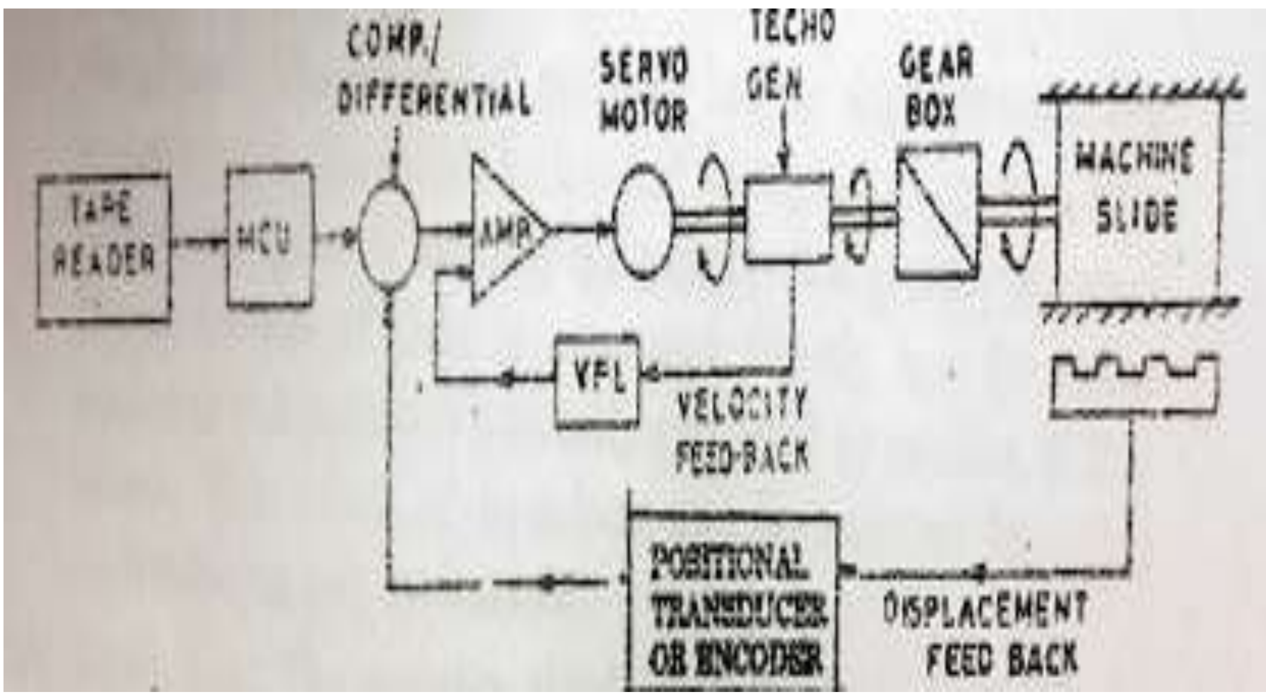

Fig.2.6: closed loop control system with Tacho-meter &encoder

In addition to above, another feedback transducer is used to control the velocity of motor in the case of continuous path system. It is essential to ensure that the cutter follows path as required by the profile.

iii. Semi-closed loop control system

In these systems, a transducer is not used for measuring the exact position of the machine slide, but it derived from the rotary motion of the lead screw by a pinion and gear arrangement. Thus the linear displacement of the machine slide is directly proportional to the rotary displacement. This system is “ closed” in the sense that it give feedback for displacement but “not closed” in the sense that it largely depends upon the accuracy of the screw or the gear arrangement. These systems reduce the bulkiness by removing one part positional transducer.

2.4.2 Classification based on motion control system

Some machine tool like drilling, boring and milling machines require that the cutting tool and work piece shall be placed at certain positions and also one moved relative to each other. Based on the relative motion, so classification can as follows:

i. Point to point motion control system

Point-to-point (PTP) motion control system are those in which importance in given to position the cutting tool at a predefined location relative to the work pice. The machining operating is done only after the tool has been taken a particular position w.r.t. position of work or vice-versa i.e. movement of slide ceases. Hence it is required that the tool reaches the particular fixed point in the shortest time span and with shortest path.

ii. Straight line motion or paraxial control system

The CNC system, in which the tool work along a straight line in the direction of a major co-ordinate axis, such as along the direction of feed during turning, boring or milling operation at a controlled rate, are known as straight line control system.

iii. Contouring/continuous path motion control system

The CNC system, in which the position of table along with the speed (velocity) and feed of tool is under continuous control. The cutting takes place while the position of workspace and tool are changing, are known as continuous motion control system.

iv. Combined motion control system

All these above mentioned PTP, straight-line and contouring motion control system have their individual specialty in operations. For taking advantage of these specialties, the control system are combined in C-L and P-L groups. For example, PTP system are faster as compared to contouring mode system, so both of these can be combined if a profile is having some portion as contour and other require only positioning. Thus implementing PTP in latter stage of operation increases the speed.

2.4.3 Classification based on circuit technology

In NC systems, the problem arise to calculate and measure the dimension at some defined location and their displacement with respect to some location point. These measuring devices affect the precision of an NC system. On the basis of the type circuitry used in these devices, they are of two type.

i. Analog control system

In analog system, the value vary continuously with respect to the quantities. An analog needle type meter is the simplest example of these analog systems, in which even a small value of order .00001 inch is shown by small deflection in needle. The accuracy in these systems can be achieved by the precision of sensors which are used.

ii. Digital control system

The value are measured in steps in these control system. For example, if a distance is to be measured in this system having least count of 0.01 for smaller tolerance. Thus if there is a travel of 0.004 i.e. less than 0.01, it will note effect the reading value. Thus the value will change only after the quantity has changed by at least 0.01.

Normally, there is a confusion that which type of circuit technology of control is used in an NC, because the information is repeatedly converted from analog to digital and digital to analog. But here analog are the systems in which the data are converted to analog before processing and similarly for digital systems, the data is converted to digital before processing.

2.5 CNC operation

The machine can be a milling machine, lathe, router, welder, grinder, laser or water jet cutter, sheet metal stamping machine, robot, or many other types of machines. For larger industrial machines, the computer is generally an on-board dedicated controller. But for more hobbyist types of machines, or with some retrofits, the computer can be an external PC. The CNC controller works together with a series of motors and drive components to move the machine axes in a controlled way, executing the programmed motions. On the industrial machines there is usually a sophisticated feedback system that constantly monitors and adjusts the cutter's speed and position.

CNC machine setup and operation follows the process shown in down.

2.5.1 Pre-Start

Before starting the machine, check to ensure oil and coolant levels are full. Check the machine maintenance manual if you are unsure about how to service it. Ensure the work area is clear of any loose tools or equipment. If the machine requires an air supply, ensure the compressor is on and pressure meets the machine requirements.

2.5.2 Start/Home

Turn power on the machine and control. The main breaker is located at the back of the machine. The machine power button is located in the upper-left corner on the control face.

2.5.3 Load Tools

Load tools into the tool carousel in the order listed in the CNC program tool list.

2.5.4 Set Tool Length Offsets

For each tool used, jog the machine to find and then set the TLO.

2.5.5 Set Fixture Offset X/Y

Once the vise or other fixture is properly installed and aligned on the machine, set the fixture offset to locate the part XY datum.

2.5.6 Set Fixture Offset Z

Use a dial indicator and 1-2-3 block to find and set the fixture offset Z.

2.5.7 Load CNC Program

Download the CNC program from your computer to the machine control using RS-232 communications, USB flash memory, or floppy disk.

2.5.8 Run Program

Run the program, using extra caution until the program is proven to be error-free.

2.5.9 Adjust Offsets as Required

Check the part features and adjust the CDC or TLO registers as needed to ensure the part is within design specifications.

2.5.10 Shut Down

Remove tools from the spindle, clean the work area, and properly shut down the machine. Be sure to clean the work area and leave the machine and tools in the location and condition you found them.

2.6 Applications

The applications of CNC include both for machine tool as well as non-machine tool areas. In the machine tool category, CNC is widely used for lathe, drill press, milling machine, grinding unit, laser, sheet-metal press working machine, tube bending machine etc. Highly automated machine tools such as turning center and machining center which change the cutting tools automatically under CNC control have been developed. In the non-machine tool category, CNC applications include welding machines (arc and resistance), coordinate measuring machine, electronic assembly, tape laying and filament winding machines for composites etc.

CNC machines are used for various machining operations like shearing, flame or plasma cutting, punching, laser cutting, forming, and welding and many other applications. To bring the plates to their final shape CNC lasers and CNC plasma cutters are used commonly. To punch the holes in the plates of all sizes CNC turret punch presses are used. And if you want to bend the plate so as to give it a final shape, you can use CNC press brakes. In some cases the CNC back gages are coupled with the shearing machines, this enables controlling the length of the plate to be sheared as for different applications.

In addition the metal removing industries remove the metal from the raw material to give it the desired as per the requirements. These can be the automotive industries for making the shafts, gears, and many other parts. It can be manufacturing industries for making the various rounded, square, rectangular, threaded and other jobs. There are many other industries where the metal removal works are performed. All these metal removal works are performed by different machine tools like lathe, milling machine, drilling machine, boring machine, shaping machine, reamer, etc. Traditionally these machines are operated by the operators, but the CNC versions of all these machines are now used extensively. You can carry out almost all machining operations with the CNC machining centers. You can also carry out all the turning operations such as facing, boring, turning, grooving, knurling, and threading on your CNC turning centers. On your CNC grinders you can carry out the grinding of the internal diameter, outer diameter, and also the flat surfaces. The Contour Grinding technology enables you to grind surfaces of all shapes. [1]

CHAPTER THREE

ELECTRICAL COMPONENTS OF CNC SYSTEM

3.1 Introduction

The most popular motors for motion control systems in CNC machines are stepper motors and permanent-magnet (PM) DC brush-type and brushless DC servomotors. Stepper motors are selected for systems because they can run open-loop without feedback sensors. These motors are indexed by digital pulses that turn their rotors a fixed fraction or a revolution where they will be clamped securely by their inherent holding torque.

However, a feedback loop can improve the positioning accuracy of a stepper motor without incurring the higher costs of a complete servo system. Some stepper motor motion controllers can accommodate a closed loop.

Brush and brushless PMDC servomotors are usually selected for applications that require more precise positioning. Both of these motors can reach higher speeds and offer smoother low-speed operation with finer position resolution than stepper motors, but both require one or more feedback sensors in closed loops, adding to system cost and complexity. Any servomotor with brush commutation can be unsuitable for some applications due to the electromagnetic interference (EMI) caused by brush arcing or the possibility that the arcing can ignite nearby flammable fluids, airborne dust, or vapor, posing a fire or explosion hazard. The EMI generated can adversely affect nearby electronic circuitry. In addition, motor brushes wear down and leave a gritty residue that can contaminate nearby sensitive instruments or precisely ground surfaces. Thus brush-type motors must be cleaned constantly to prevent the spread of the residue from the motor. Also, brushes must be replaced periodically, causing unproductive downtime. Brushless DC PM Motors overcome these problems and offer the benefits of electronic rather than mechanical commutation. Built as inside out DC motors, typical brushless motors have PM rotors and wound stator coils. Commutation is performed by internal noncontact Hall-effect devices (HEDs) positioned within the stator windings. The HEDs are wired to power transistor switching circuitry, which is mounted externally in separate modules for some motors but is mounted internally on circuit cards in other motors. Alternatively, commutation can be performed by a commutating encoder or by commutation software resident in the motion controller or motor drive. Brushless DC motors exhibit low rotor inertia and lower winding thermal resistance than brush-type motors because their high-efficiency magnets permit the use of shorter rotors with smaller diameters. Moreover, because they are not burdened with sliding brush-type mechanical contacts, they can run at higher speeds (50,000 rpm or greater), provide higher continuous torque, and accelerate faster than brush-type motors. Nevertheless, brushless motors still cost more than comparably rated brush-type motors (although that price gap continues to narrow) and their installation adds to overall motion control system cost and complexity.

3.2 Stepper Motors

A stepper or stepping motor is a DC motor whose shaft is indexed through part of a revolution or step angle for each DC pulse sent to it. Trains of pulses provide input current to the motor in increments that can “step” the motor through 360°, and the actual angular rotation of the shaft is directly related to the number of pulses introduced. The position of the load can be determined with reasonable accuracy by counting the pulses entered. The stepper motors suitable for most open-loop motion control applications have wound stator fields (electromagnetic coils) and iron or permanent magnet (PM) rotors. Stepper motors depend on external controllers to provide the switching pulses for commutation. Because controllers can step most motors at audio frequencies, their rotors can turn rapidly. Between the application of pulses when the rotor is at rest, its armature will not drift from its stationary position because of the stepper motor's inherent holding ability or detent torque. These motors generate very little heat while at rest, making them suitable for many different instrument drive-motor applications in which power is limited. The three basic kinds of stepper motors are permanent magnet, variable reluctance, and hybrid. [2]

3.2.1 Types of Stepper Motors

There are three types of stepper motors:

i. Variable Reluctance Stepper Motor

It has wound stator poles but the rotor poles are made of a ferromagnetic material. It can be of the single stack type or multi-stack type which gives smaller step angles. Direction of motor rotation is independent of the polarity of the stator current. It is called variable reluctance motor because the reluctance of the magnetic circuit formed by the rotor and stator teeth varies with the angular position of the rotor. As a variable speed machine, VR motor is sometime designed as a switched-reluctance motor.

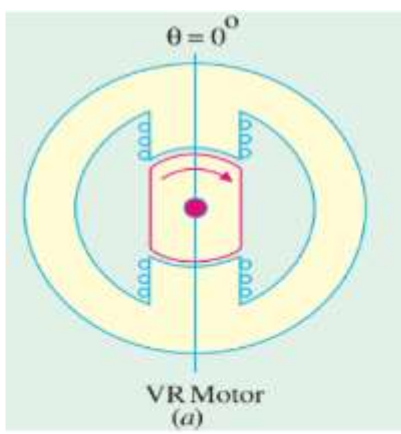

Fig.3.1 VR stepper

ii. Permanent Magnet Stepper Motor

It has wound stator poles but its rotor poles are permanently magnetized. The permanent magnet motor, also referred to as a "canstack" motor, has, as the name implies, a permanent magnet rotor. It is a relatively low speed, low torque device with large step angles of either 45 or 90 degrees. Its simple construction and low cost make it an ideal choice for non-industrial applications, such as a line printer print wheel positioner. Similarly, *PM* stepper motor is also called variable speed brushless dc motor.

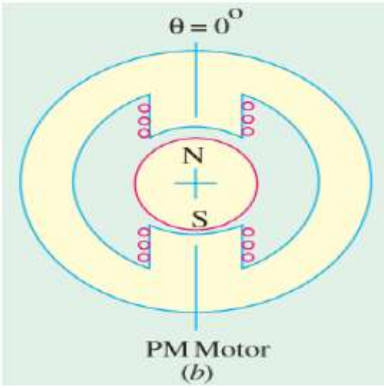

Fig.3.2 PM Stepper

iii. Hybrid Stepper Motor

It has wound stator poles and permanently-magnetized rotor poles. It is best suited when small step angles of 1.8º, 2.5º etc. are required.

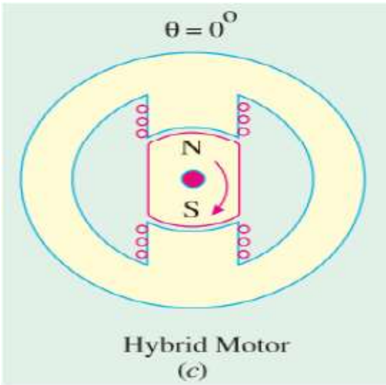

Fig.3.3: Hybrid stepper

The same controller circuit can drive both hybrid and PM stepping motors. The most common step angles for PM motors are 45 and 90°, but motors with step angles as fine as 1.8° per step as well as 7.5, 15, and 30° per step are generally available Some 5-phase motors have high resolutions of 0.72° per step (500 steps per revolution). With a compatible controller, most PM and hybrid motors can be run in half-steps, and some controllers are designed to provide smaller fractional steps, or micro steps. Hybrid stepper motors capable of a wide range of torque values are available commercially. This range is achieved by scaling length and diameter dimensions. Hybrid stepper motors are available in NEMA size 17 to 42 frames, and output power can be as high as 1000 W peak.

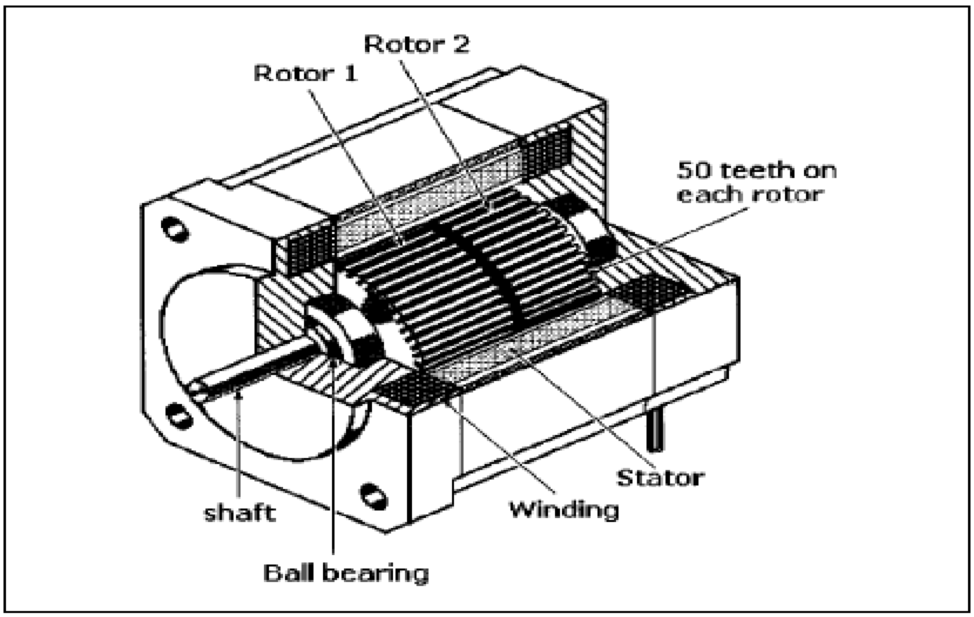

Fig.3.4: Cutaway view of a 5-phase hybrid stepping motor. A permanent magnet is within the rotor assembly, and the rotor segments are offset from each other by 3.5°.

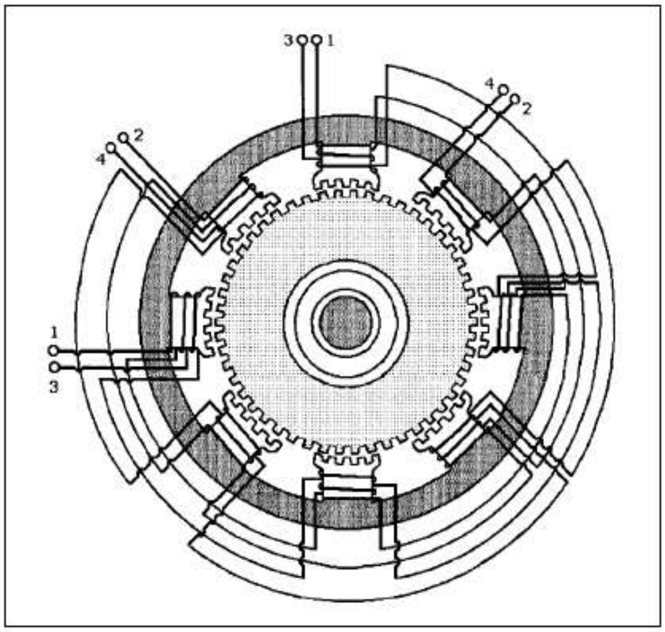

Fig.3.5: Cross-section of a hybrid stepping motor showing the segments of the magnetic core rotor and stator poles with its wiring diagram.

3.3 Permanent-Magnet DC Servomotors

Permanent-magnet (PM) field DC rotary motors have proven to be reliable drives for motion control applications where high efficiency, high starting torque, and linear speed–torque curves are desirable characteristics. PM DC servomotors increased in popularity with the introduction of stronger ceramic and rare-earth magnets made from such materials as neodymium–iron–boron and the fact that these motors can be driven easily by microprocessor-based controllers. The replacement of a wound field with permanent magnets eliminates both the need for separate field excitation and the electrical losses that occur in those field windings. Because there are both brush-type and brushless DC servomotors, the term DC motor implies that it is brush type that requires mechanical commutation unless it is modified by the term brushless. The increased field strength of the ceramic and rare-earth magnets permitted the construction of DC motors that are both smaller and lighter than earlier generation comparably rated DC motors with alnico (aluminum–nickel–cobalt or AlNiCo) magnets. Moreover, integrated circuitry and microprocessors have increased the reliability and cost effectiveness of digital motion controllers and motor drivers or amplifiers while permitting them to be packaged in smaller and lighter cases, thus reducing the size and weight of complete, integrated motion control systems.

3.3.1 Brush-Type PM DC Servomotors

The design feature that distinguishes the brush-type PM DC servomotor, as shown in Figure 1-17, from other brush-type DC motors is the use of a permanent-magnet field to replace the wound field. Permanent-magnet DC motors, like all other mechanically commutated DC motors, are energized through brushes and a multi segment commutator. While all DC motors operate on the same principles, only PM DC motors have the linear speed–torque curves shown in Figure 1-18, making them ideal for closed-loop and variable-speed servomotor applications. These linear characteristics conveniently describe the full range of motor performance.

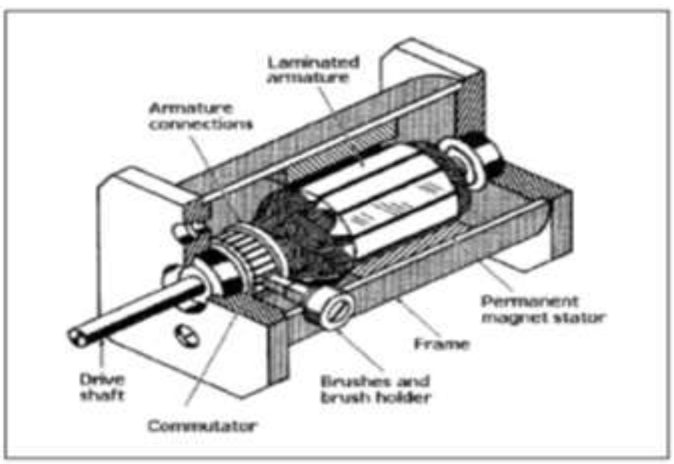

Fig.3.6: Fractional horsepower permanent-magnet DC servomotor.

It can be seen that both speed and torque increase linearly with applied voltage, indicated in the diagram as increasing from V1 to V5. The stators of brush-type PM DC motors are magnetic pole pairs. The commutator is staggered from the rotor poles, and the number of its segments is directly proportional to the number of windings. If the connections of a PM DC motor are reversed, the motor will change direction, but it might not operate as efficiently in the reversed direction.

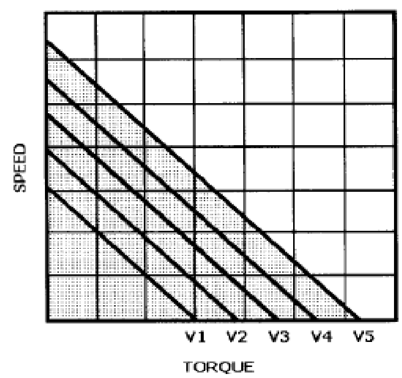

Fig.3.7: A typical family of speed/torque curves for a permanent magnet DC servomotor at different voltage inputs, with voltage increasing from left to right (V1 to V5).

3.3.2 Brushless PM DC Motors

Brushless DC motors exhibit the same linear speed–torque characteristics as the brush-type PM DC motors, but they are electronically commutated. The construction of these motors, as shown in Fig.3.8, differs from that of a typical brush-type DC motor in that they are "inside-out." In other words, they have permanent magnet rotors instead of stators, and the stators rather than the rotors are wound. Although this geometry is required for brushless DC motors, some manufacturers have adapted this design for brush-type DC motors. The mechanical brush and bar commutator of the brushless DC motor is replaced by electronic sensors, typically Hall-effect devices (HEDs) [2]. Hall effect used in BLDC motors, whenever rotor magnetic poles (N or S) pass near the hall sensor, they generate a HIGH or LOW level signal, which can be used to determine the position of the shaft.[3]

They are located within the stator windings and wired to solid-state transistor switching circuitry located either on circuit cards mounted within the motor housings or in external packages.

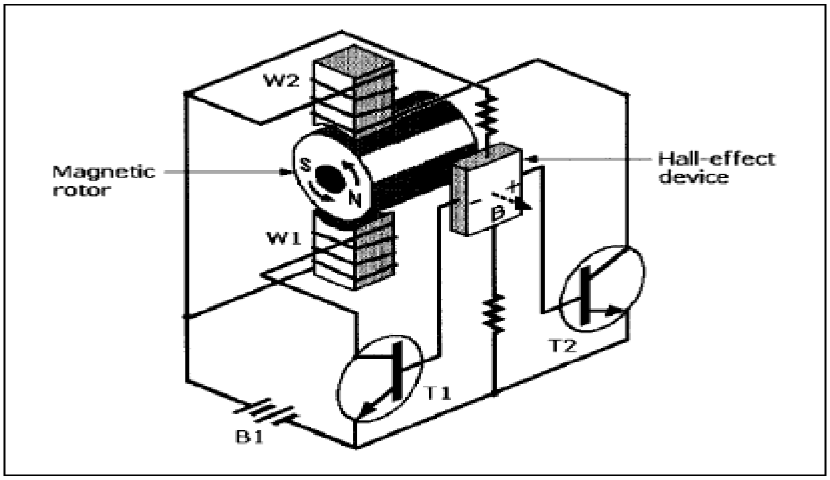

Fig.3.8: Simplified diagram of Hall-effect device (HED) commutation of a brushless DC motor.

3.4 Electronics Commutation Principle

BLDC commutation relies on feedback on the rotor position to decide when to energize the corresponding switches to generate the biggest torque. The easiest way to accurately detect position is to use a position sensor. The most popular position sensor device is Hall sensor. Most BLDC motors have Hall sensors embedded into the stator on the non-driving end of the motor.

A three-phase BLDC motor requires three Hall sensors to detect the rotor's position. Based on the physical position of the Hall sensors, there are two types of output: a 60° phase shift and a 120° phase shift. Combining these three Hall sensor signals can determine the exact commutation sequence.

Figure shows the commutation sequence of a three-phase BLDC motor driver circuit for counter-clockwise rotation. Three Hall sensors—"a," "b," and "c"—are mounted on the stator at 120° intervals, while the three phase windings are in a star formation. For every 60° rotation, one of the Hall sensors changes its state; it takes six steps to complete a whole electrical cycle. In synchronous mode, the phase current switching updates every 60°. For each step, there is one motor terminal driven high, another motor terminal driven low, with the third one left floating. Individual drive controls for the high and low drivers permit high drive, low drive, and floating drive at each motor terminal. However, one signal cycle may not correspond to a complete mechanical revolution. The number of signal cycles to complete a mechanical rotation is determined by the number of rotor pole pairs. Every rotor pole pair requires one signal cycle in one mechanical rotation. So, the number of signal cycles is equal to the rotor pole pairs.

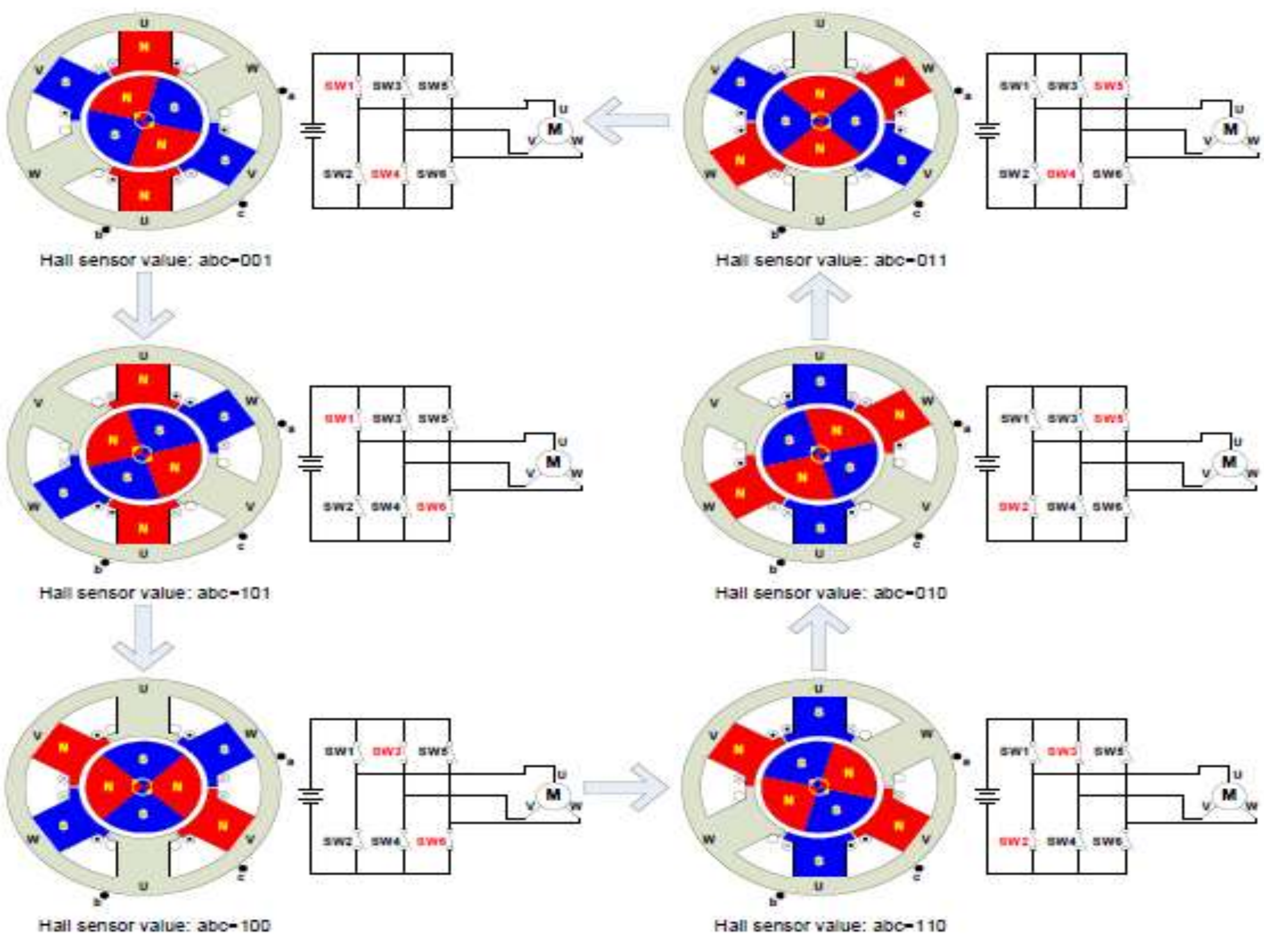

Fig.3.9: Three-Phase BLDC Motor Commutation Sequence

Figure shows the timing diagrams where the phase windings—U, V, and W—are either energized or floated based on the Hall sensor signals a, b, and c. This is an example of Hall sensor signal having a 120° phase shift with respect to each other, where the motor rotates counter-clockwise. Producing a Hall signal with a 60° phase shift or rotating the motor clockwise requires a different timing sequence. To vary the rotation speed, use pulse width modulation signals on the switches at a much higher frequency than the motor rotation frequency. Generally, the PWM frequency should be at least 10 times higher than the maximum motor rotation frequency. Another advantage of PWM is that if the DC bus voltage is much higher than the motor-rated voltage, so limiting the duty cycle of PWM to meet the motor rated voltage controls the motor. [2]

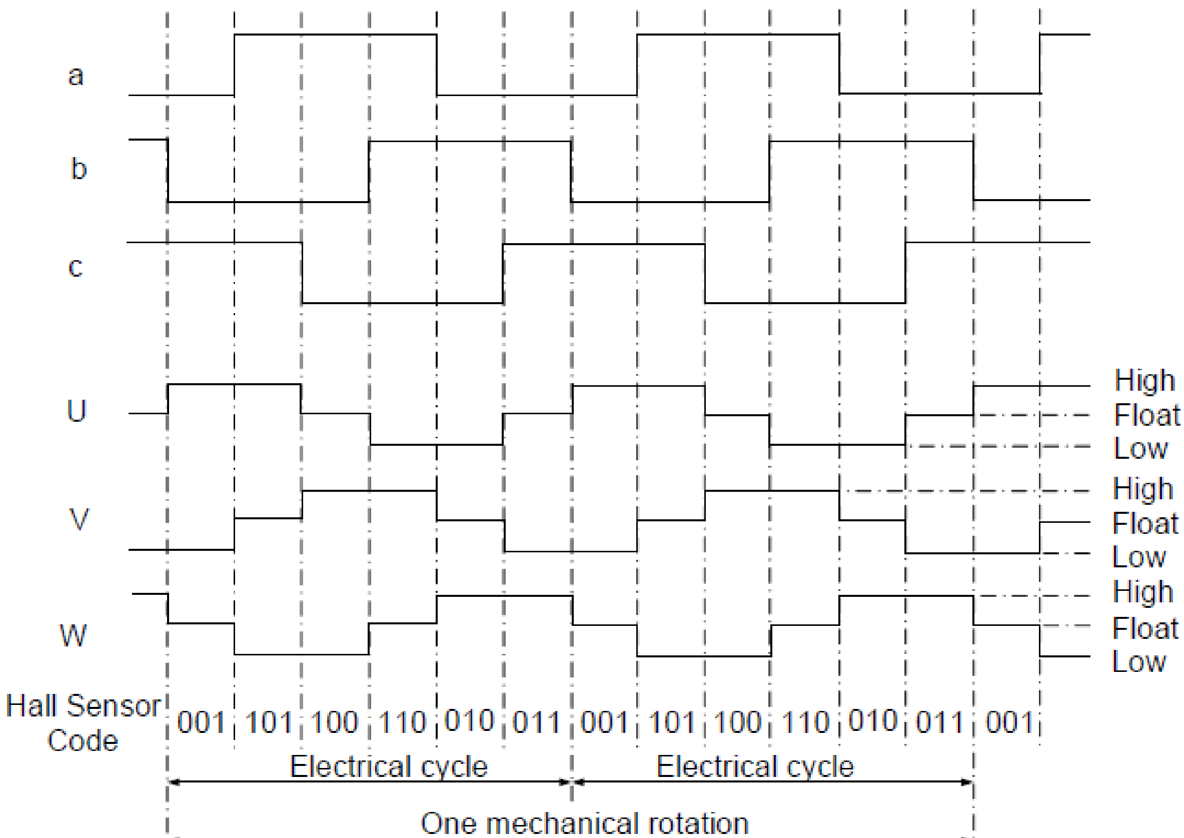

Fig.3.10: Three-phase BLDC motor sensor versus drive timing

3.5 The control system

A servo motor controller is a circuit that is used to control the position of a servo motor. It is also called as a servo motor driver. A servo motor controller consists of a controller, the servo motor and the power supply unit. Servo motor driver may be used to control a single servo or even a group of servo motors. In many application where servo motor controlling is the mainstay of the task to be accomplished, the controller must drive more than one servo. An example of this is an RC airplane, which uses many servos.

3.5.1 Essential Components

There are two essential components:

i. Micro-controller

A servo motor is driven by applying the voltage signal to it regular intervals. The servo is sensitive to timing variations. A pulse of specific width has to be applied at specific intervals of time. Typically, the duration of pulse varies from 0ms to 2.2ms and the repetition rate is 50Hz to 60Hz. For precise position control, the controller that is chosen must have timers that have the required resolution. Also, if more than one motor has to be controlled simultaneously, the processor clock must be fast enough. So that its internal PWM can be utilized. However, the selection of micro-controller depends totally on the designer and the application requirements.

ii. Power Supply

The design of the power supply unit servo motor controller depends on the number of servo motors that are interfaced to the board. Servo motors operate from 4.8V to a 6V supply voltage. The typical value is 5v. Applying voltages greater than the supply voltage is not advisable as it may render the motor permanently useless. The current draw of the motor is variable and depends on the torque that it generates.

Also it will draw less current when in idle mode and more current when it is running. A servo motors maximum current draw is given as its stall current. This is the maximum current it will draw when running with the maximum torque before it stops due to overload. This current value can be as high as 1 A for some motors. For a single motor control a voltage regulator can be used along with a suitable heat sink. But when multiple motors need to be interfaced, a high quality supply with higher current rating must be used. A SMPS (Switched mode power supply) can be a good option.

Block Diagram below showing interconnections in a Servo Motor Driver

Fig.3.11: servo motor drive

3.5.2 Controlling Servo Motor:

The servo motor has three terminals.

i. Position signal (PWM) Pulses.

ii. Vcc (From Power Supply).

iii. Ground.

The servo motor angular position is controlled by applying PWM pulses of specific width. The duration of pulse varies from about 0.5ms for 0 degree rotation to 2.2ms for 180 degree rotation. The pulses need to be given at frequencies of about 50Hz to 60Hz.

In order to generate the PWM (Pulse Width Modulation) waveform, as shown in figure below, one can use either the internal PWM module of the micro-controller or the timers can be used. Using the PWM block is more flexible as most micro-controller families design the blocks to suit the needs of application like Servo motor. For different widths of PWM pulses, we need to program the internal registers accordingly.

Now, we also need to tell the microcontroller how much it has to rotate. For this purpose, we can use a simple potentiometer and use an ADC to get the rotation angle or for more complex applications an accelerometer can be used.

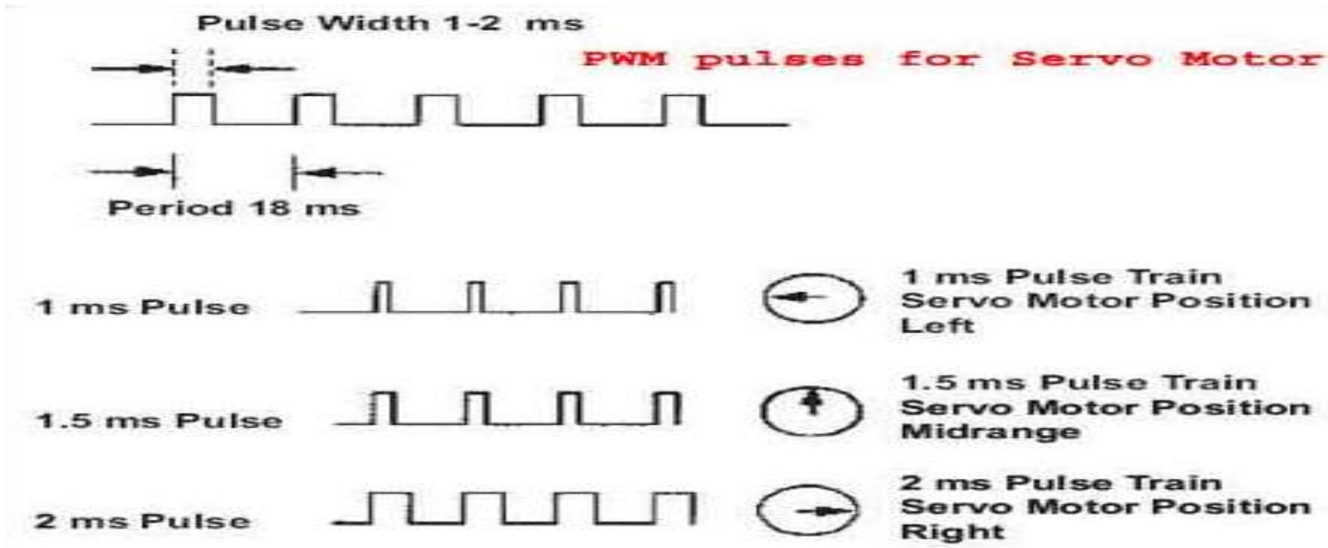

Figure 3.12 PWM pulses

3.5.3 Servo motor control using PLC

Difference between linear servo system and motion control system:

i. Linear servo system

PLC will supply pulse input to the motor drive (digital type) then the motor driver will give power through PWM to the AC servo motor. Feedback will be given by encoder to the driver and driver will do the error counter.

ii. Motion control system

PLC will supply pulse to the motion control unit. Then motion control unit will give analog input 0-10V to motor driver. The motor driver will give power through PWM to the AC servo motor. Feedback will be given by encoder to the driver and driver will give the error signal to the motion control unit to do the error counting. Start explaining on the linear servo system. Basically, there are two common ways to control the direction of the motor which is using the CW/CCW pulse mode or using the pulse plus direction mode. Two pulse are needed outputs from the servo motor to do this. It must be known the setting from the PLC of how the pulses are being output, the response time of the pulse must be known also.

To make sure to wiring the is correct. basic outputs from the PLC to the servo driver (amplifier) are the pulse outputs (two outputs are needed here, if the pulse plus direction are used, one output will supply the pulse whereas the other output will tell the servo amplifier the direction. if it’s in CW/CCW mode, one output is for clockwise pulse and the other is for counter clockwise pulses).

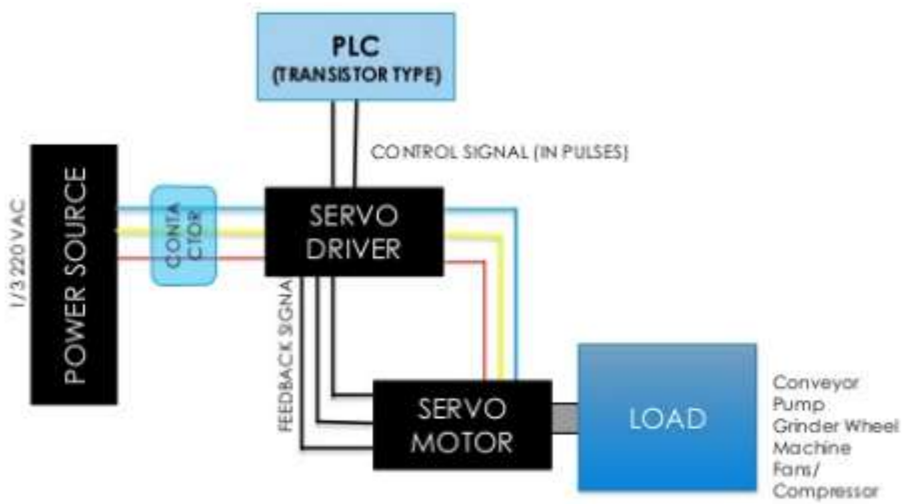

Figure 3.13 block diagram of motion control

The servo RUN output signal also needed to on the motor and reset signal to reset any alarm. Just for extra information, not all alarms can be reset from the reset signal.

For the input to the PLC from the servo driver, the feedback from the AC servo motor encoder is needed. If there is an open collector, one feedback input is enough. It will count the Z phase from the encoder and pass it back to the PLC to do the pulse count.

CHAPTER FOUR

SIMULATION OF BLDC MOTOR AND CNC

4.1 Introduction

The Brushless DC (BLDC) motor is rapidly gaining popularity by its utilization in various industries, such as appliances, automotive, aerospace, consumer, medical, industrial automation equipment and instrumentation. As the name implies, the BLDC motors do not use brushes for commutation instead of they are electronically commutated. BLDC motors have many advantages over brushed DC motors and induction motors a few of these are better speed versus torque characteristics, high dynamic response, high efficiency long operating life, noiseless operation. The major disadvantage of BLDC motor is their higher cost and relatively greater degree of complexity introduced by the power electronics converter .The speed of the motor is directly proportional to the applied voltage across the winding the speed can be altered, by varying the duty cycle of PWM signal.

A Brushless DC motor has a rotor with permanent magnets and a stator with windings. The brushes and commutator have been eliminated and the windings are connected to the control electronics energize the winding with particular sequence of switching pulses. The energized stator winding leads the rotor magnet, and switches just as the rotor aligns with the stator.

A permanent Magnet AC motor, which has a trapezoidal back EMF, is referred to as brushless DC motor (BLDC). The BLDC drive system is based on the feedback of rotor system at fixed points for commutation of the phase currents. The BLDC motor requires quasi-rectangle shaped currents fed into the machine.

Alternatively, the voltage may be applied to the motor every 120°, with current limit to hold the current within motor capabilities. Because the phase currents are excited in synchronism with the constant part of the back EMF, constant torque is generated. The electromagnetic torque of the BLDC motor is related to the product of phase, back EMF and current. The back EMF in each phase is trapezoidal in shape and is displaced by 120 electrical degrees with respect to each other in three phase machine. A rectangle current pulse is injected into each phase so that current coincides with the back EMF waveform. Hence the motor develops an almost constant toque.

The simulation model of a BLDC motor with using a PI controller, which responsible to govern the duty cycle of PWM pulses to inverter switches. The studies were conducted at different load torques using **MATLAB/SIMULINK**. [8]

4.2 PROPOSED CONTROL SCHEME

Block diagram of closed loop speed control of BLDC motor using PI controller as shown in Fig. 4.1.

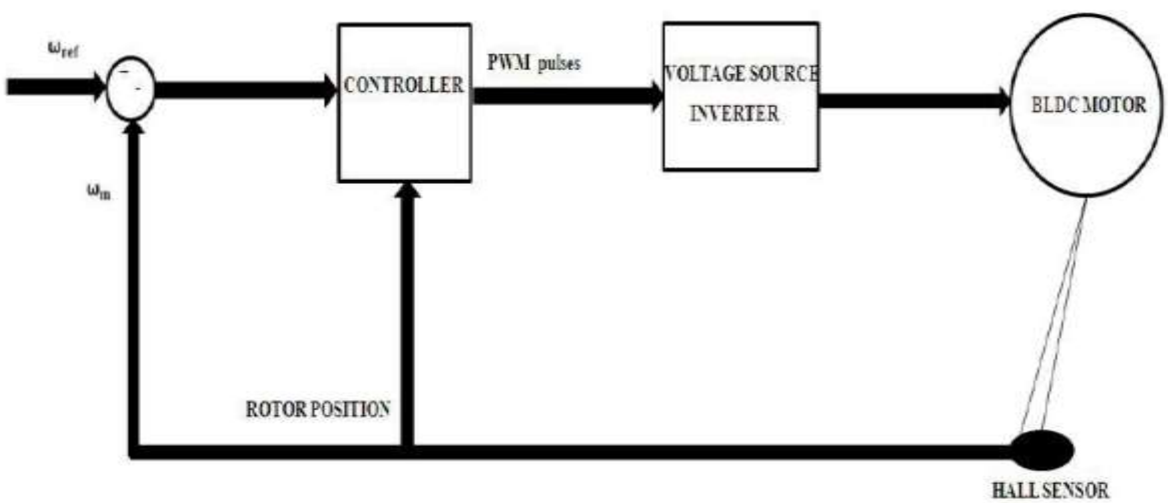

Fig.4.1: Block diagram of closed loop speed control of BLDC motor

4.3 The Matlab Simulink

The developed MATLAB/SIMULINK model in Fig4.2 provides the speed control of BLDC motor using PI Controller and the simulation results provide necessary waveforms for the analysis of closed loop speed control Of BLDC drives.

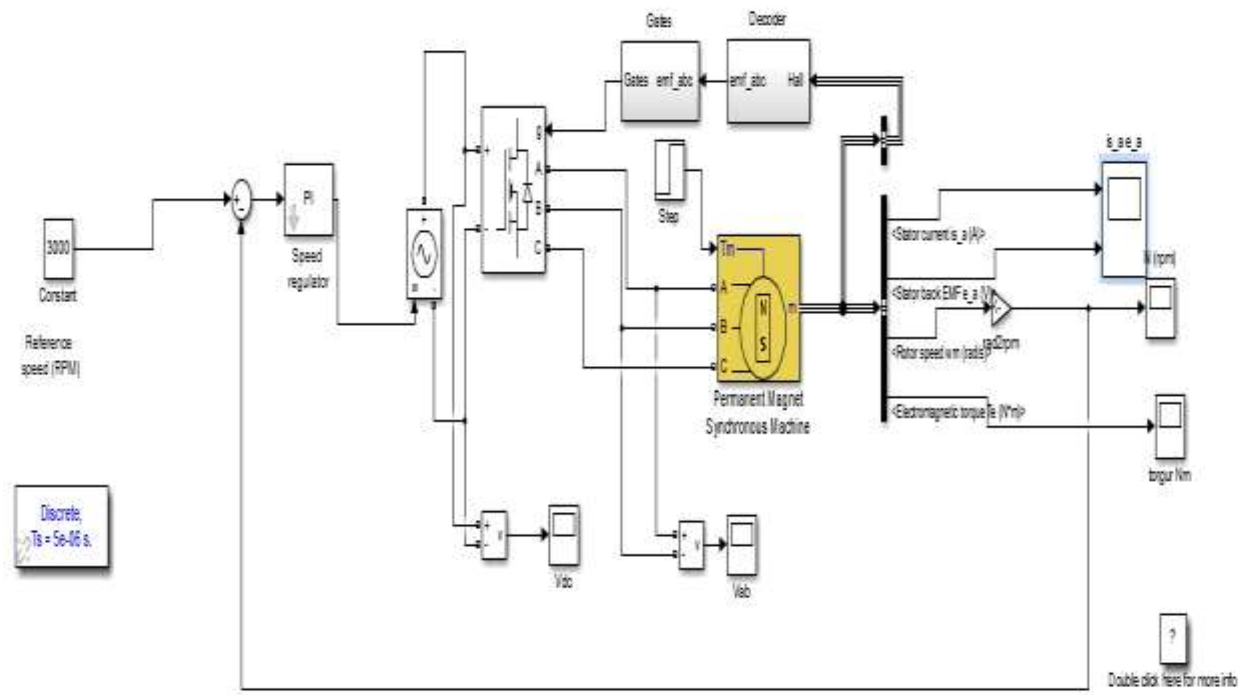

Fig.4.2: Simulation model of closed loop speed control of BLDC motor

4.3.1 Back EMF detection from hall sensor

The back EMF detection from hall sensor based on logic sequence.The model Implemented in simulation as show in Fig.4.3 to generate trapezoidal nature of back EMF from hall sensor.

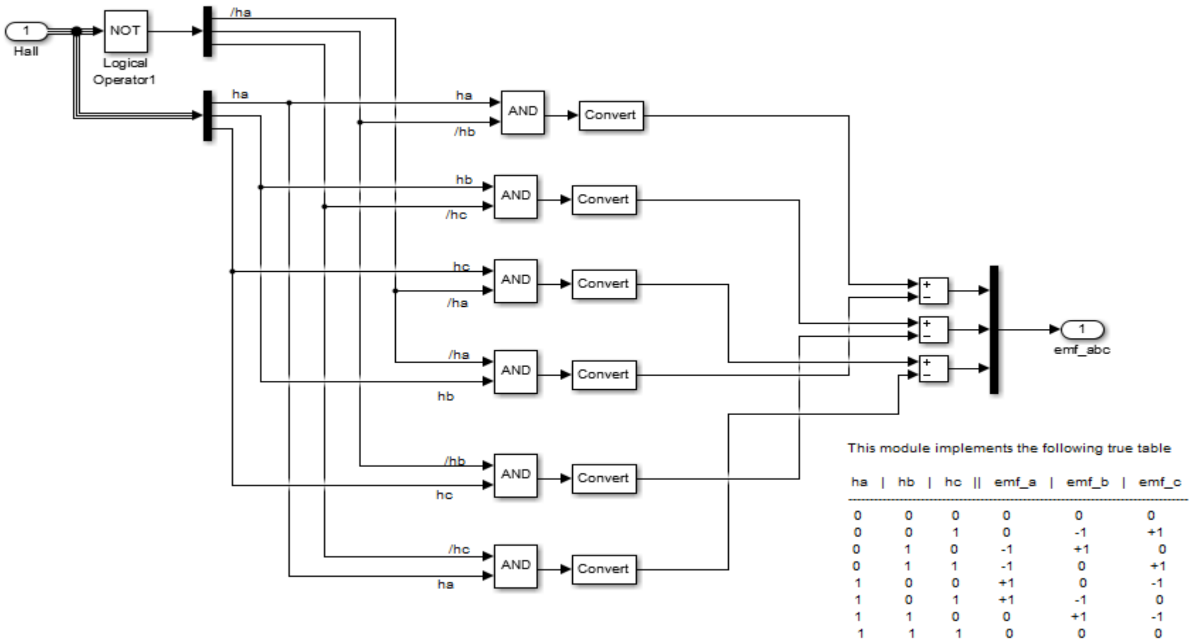

Fig.4.3: Back EMF detection from hall sensor

4.3.2 Commutation signal generation

Based on truth Table, the model developed to generate appropriate commutation signal which is controlled by duty ratio signal as shown in Fig.4.4

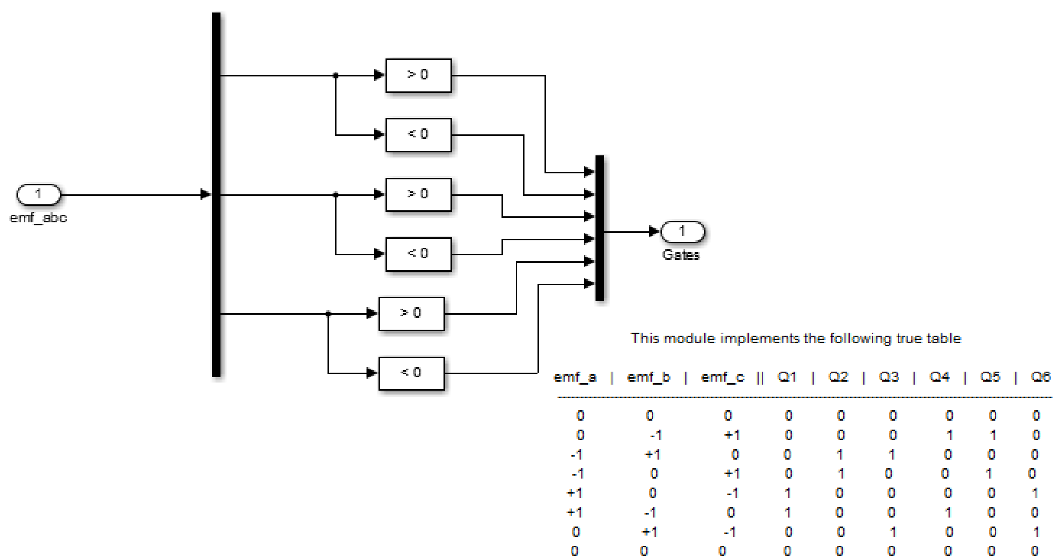

Fig.4.4: commutation signal from back EMF and duty ratio

4.3.3 Rotor speed and Motor Torque

Rotor speed of the motor is build up to speed of 3000 rpm as setting point as shown in figure 4.5. The developed motor is zero because the motor is run on no-load condition. The motor torque is shown in Fig. 4.6

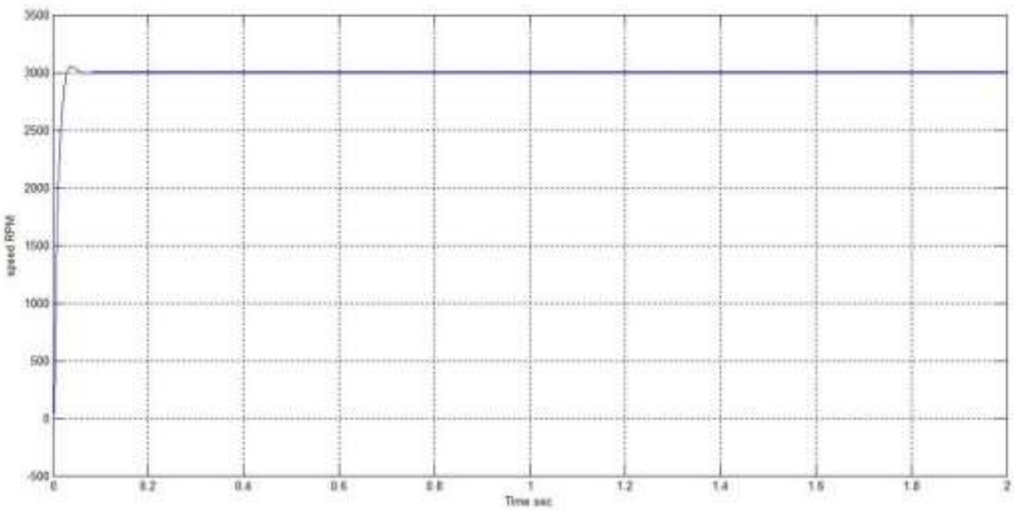

Fig.4.5: The rotor speed at no-load

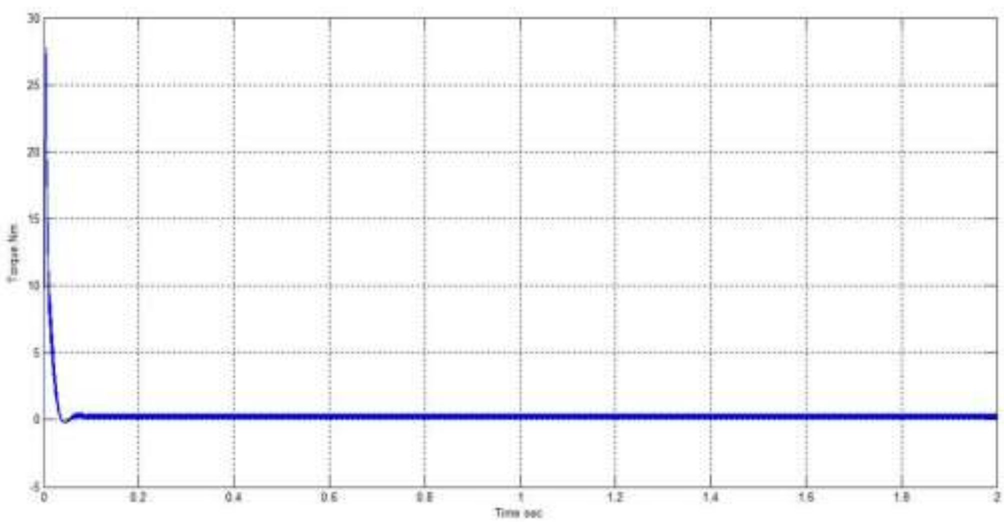

Fig.4.6: The motor torque at no-load

At load condition for the same speed 3000 rpm the speed shown in Fig4.7.And the develop motor torque is shown in Fig4.8

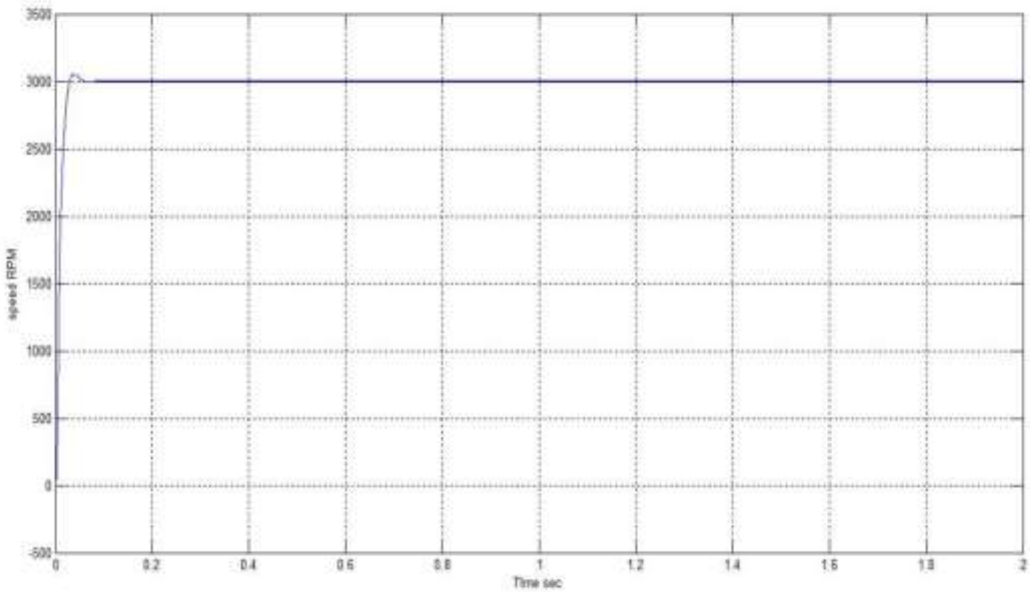

Fig.4.7: The rotor speed at load

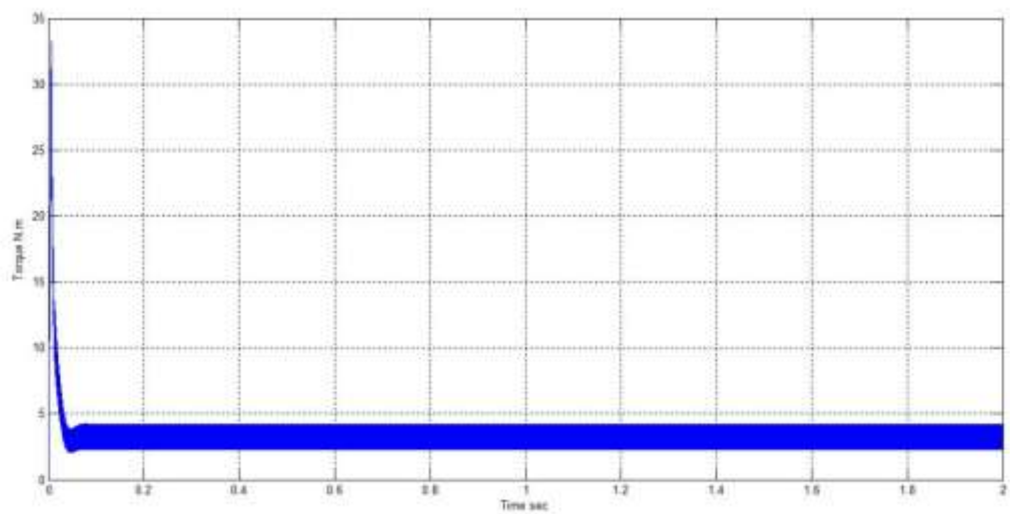

Fig.4.8: The motor torque at load

4.3.4 The stator current of phase (A)

The phase currents of the motor at no-load is shown in Fig.4.9.

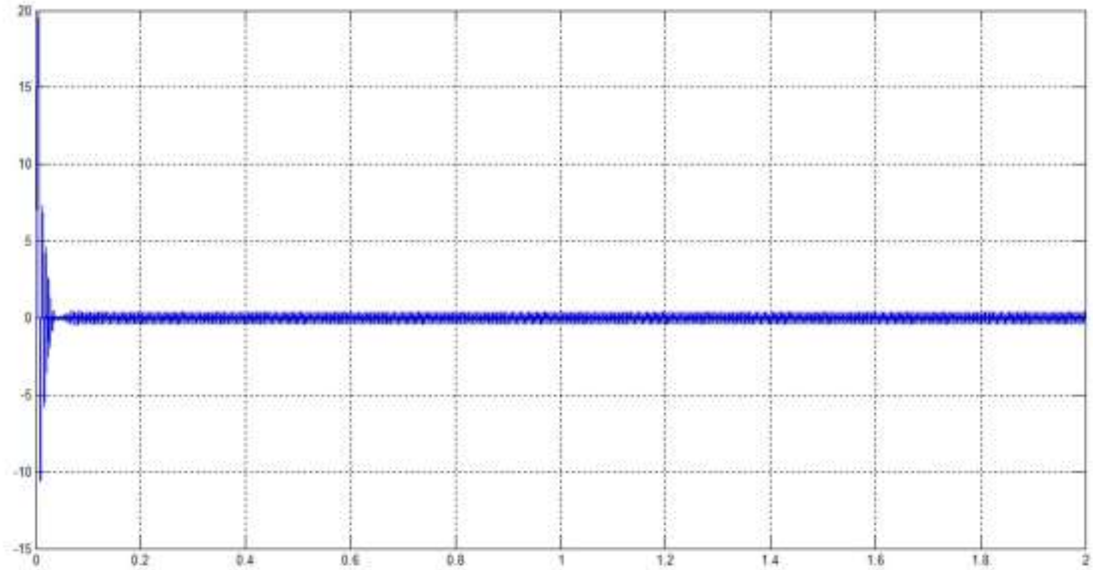

Fig.4.9: The stator current of phase A at no-load

The phase currents of the motor at load is shown in Fig.4.10.

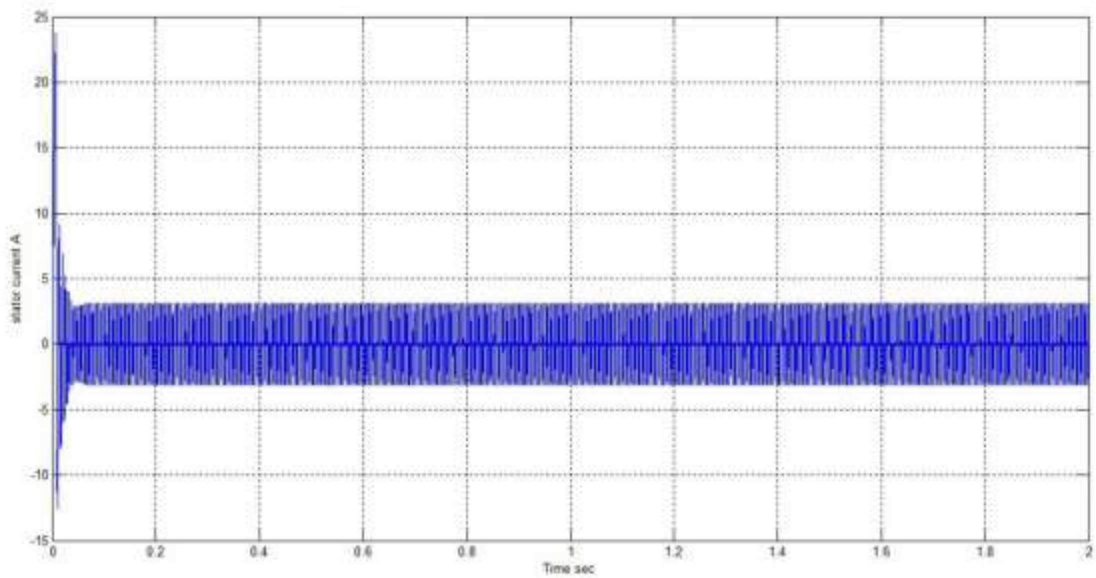

Fig.4.10: The stator current of phase A at load

4.3.5 The Back EMF of stator phase (A)

The Back EMF at no-load is shown in Fig.4.11

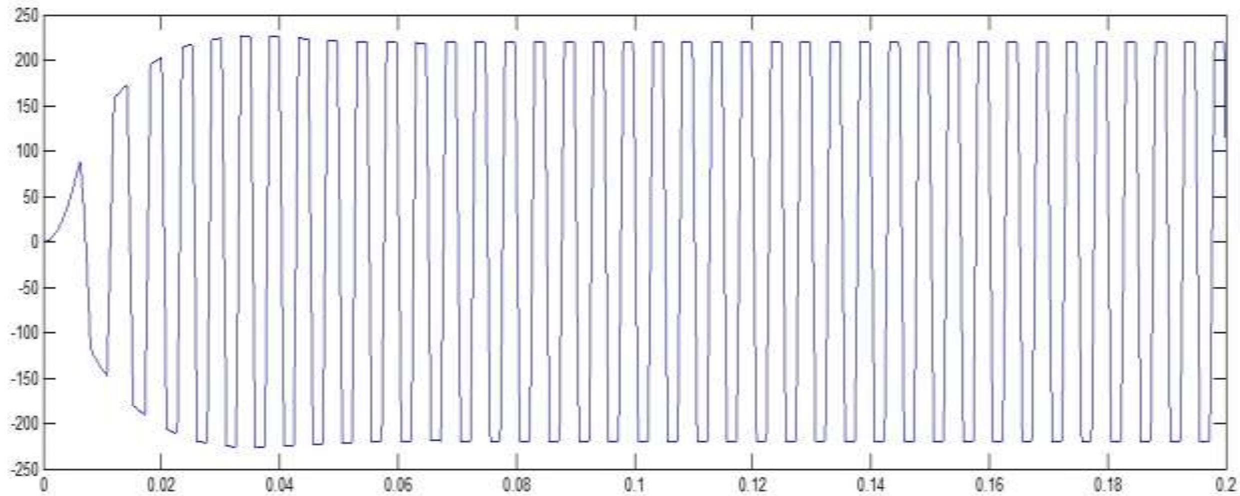

Fig.4.11: The back EMF at no-load condition

The Back EMF at load condition is shown in Fig.4.12

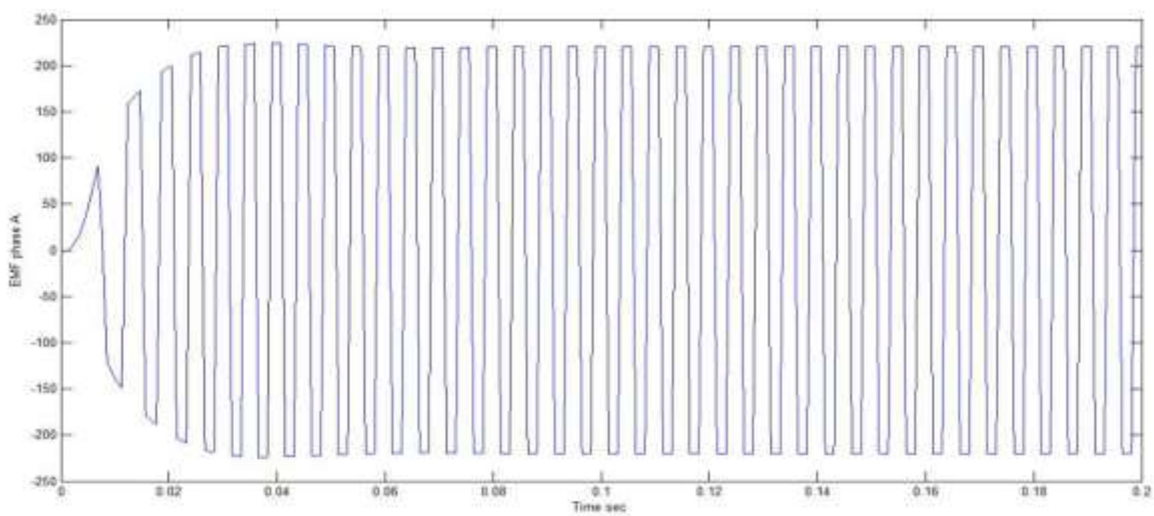

Fig.4.12: The back EMF at load condition

4.4 Programming of the CNC machine:

To start programming the CNC machine some consideration must be taken, such as for which application the programme to, awareness of the motors that used in the machine. Fig.4.13 shows the block diagram for milling CNC machine. The block diagram include CNC system, servo control unit, spindle head, encoder or any feedback technique, the program and the machine elements. [4]

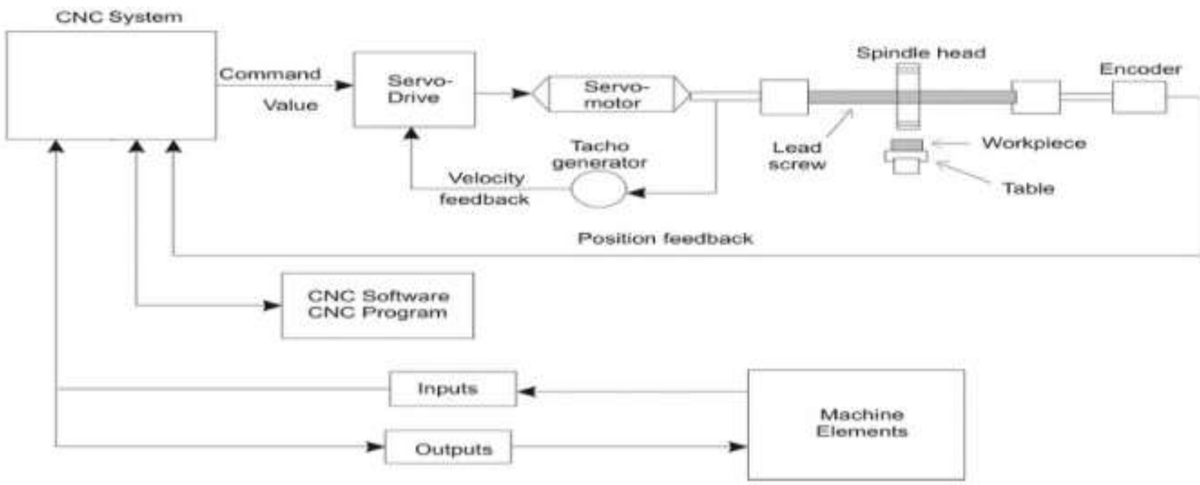

Fig.4.13: schematic diagram of CNC machine tool

The mechanical system which is assembled in such a way that the 3-axis movement is achieved by using the linear rails assembled with linear bearings. Stepper motors are mounted to the each axis as shown in Fig.4.14 which is source of motion acted according to the control signal. Each stepper motor is coupled through the shaft couplers to each of the Lead/Ball screw of each axis which is responsible for converting the rotational motion of the stepper motor to linear motion. The linear motion of each axis is carried away smoothly by the linear rail assembly connected to the each axis which is capable of load carriers and allow linear motion in each axis. [5]

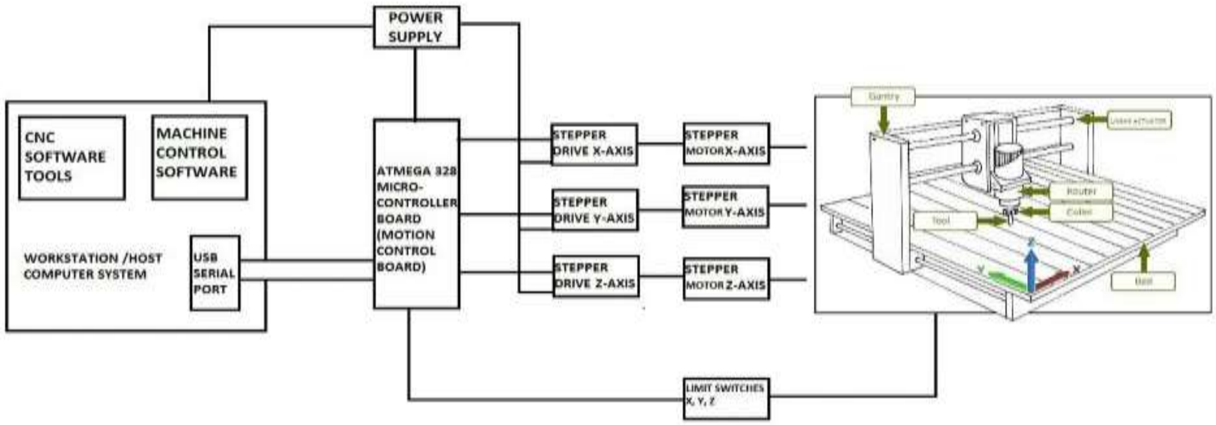

Fig.4.14: block diagram of overall process

4.4.1 Machining Process

When it need to create a part though machining the following process considered when operator want to shape any piece using machining.

Obtain a drawing.

- Select machining method.
- Decide setup method.
- Select cutting tools.
- Determine speeds and feeds.
- Machine part.

4.4.2 CNC is multi-purpose can be used to perform the following tasks

- Mills and machining centers
- Lathes and Turning Centers
- Drilling Machines
- Boring mills and Profilers
- Punch presses and Shears
- Routers

- Water Jet
- Laser Profilers
- Welding Machines
- Benders
- Flame Cutting machines

We will focus on CNC Machining mill and machining centers for the first part. Milling centers have a typical system set up of three coordinates (X, Y, Z) .The part is mounted and the cutting tools will rotate around. As a machinist and programmer you are responsible for many of the aspects of the operation and quality of production. The machine operator will typically handle the setup and quality control of the parts but the CNC programmer may include some of the operator's duties as well.

4.4.3 Understanding Coordinate System

Make sure to note the coordinate system of your machine. This is a typical layout but what is important to remember is even though the table may move and tool may be stationary you need to know what respect to what your coordinate system is set up. You may see something as a positive motion but it may actually need to be coded as a negative motion. First order of business should always be to identify the coordinate system.

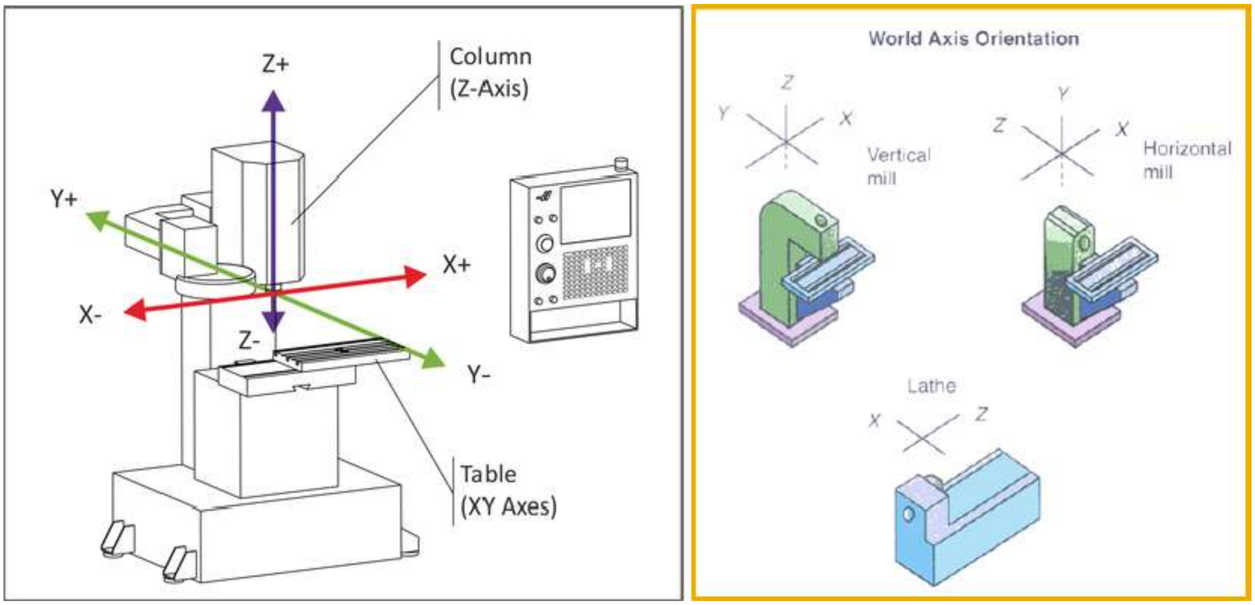

Fig.4.15: explaining the axes

4.4.4 G-code

G-code is just the language used to control CNC machines. If you are involved with CNC machining then you should at least know a little bit of G-code to understand what is going on. This will allow you to make simple changes to G-code, and understand what the CAM program is doing. [7]

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Electric machines are used to generate electrical power in power plants and provide mechanical work in industries. The DC machine is considered to be a basic electric machine. The Permanent Magnet Brushless DC (PMBLDC) motors are one of the electrical drives that are rapidly gaining popularity, due to their high efficiency, good dynamic response and low maintenance. The brushless DC (BLDC) motors and drives have grown significantly in recent years in the appliance industry and the automotive industry. BLDC drives are very preferable for compact, low cost, low maintenance, and high reliability system. [8]

The control scheme for speed control of BLDC motor using PI controller is proposed. The performance of the BLDC motor shows satisfactory performance under no- load and variable load condition.

The simulation of PI controller, using MATLAB/SIMULINK to control the speed of BLDC motor, proves that the desired speed is attained with shorter response time. The dynamic characteristic of motor is obtained and the analysis reveals that PI controller is capable of controlling the motor drive over wide speed range. [8]
The computer numerical control machine useful machine and nowadays it has been an important machine which spread over all industries as well as its reliable and capable of achieving various job in different field. The most serious advantage of this machine it's easy to code in addition to that editable code availability.

CNC machine has a built-in computer, which is used to store and sent instructions to different parts of the machine in the form of code. The machine responds to this coded information in a precise and ordered manner to carry out various machining functions. [9]

5.2 Recommendations

In this project the control of speed in the servo motor have been studied by taken the brushless DC servo motor as an example which it used in the computer numerical control machine.

And this motor is not only motor that used in the machine but it may consist of other motors such as stepper motor may be two motors, three motors and even may be four motors, according to the number of the axis that the machine will design for, so the following point recommended to other researchers whose would have read this project.

- Control of speed and position of other motors.
- Take other kind of computer numerical control machine purpose like lathing, benders and flame Cutting machines.

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APPENDEX A

Example for milling program

Frist thing is to step up a unit and load the correct machine-from the setting chose the machine and the unit of the measurement millimeter- and then select the tools that application needed included the mill work-piece are follows

1- Sample flat mill: with diameter 10 and length 50.
2- Sample pointed drill: with diameter 10, length and tip angle 80.

/add part to machine

$AddRegPart 1 30, 30 (to add sample block in X, Y position where it will place it from the origin point)

/set zero point

G92 X30 **Y**30 **Z**25 (G92 use to reposition the origin point-reference point-in absolute programming mode)

/set up tool and change

T1 M06 (sample flat mill) (T1 use to select the tool you need, M6 to change the previous tool)

/move tool to location where we can start the work

G00 **X**15 **Y**15 **Z**2 **M**3 (G00 use for fast traverse, reposition the new location)

/change the motion of tool ,set feed and spindle

G01 **Z**-5 **F**250 **S**2000 **M**03 (G01 use for linear feed traverse the tool NO:1 will be down in Z by 5milli, feed specified to 250, spindle speed specified 2000 rpm,M3 use to specify the spindle rotation direction in clock wise)

/move one direction in y (from the zero point)

y70 (move flat mill 70milli in Y axis)

/set to arc motion and arc center (interpolates motion- move in X and Y in same the time and specify the arc center)

G02 **X**30 **Y**85 **I**15 **J**0 (interpolates clock wise X, Y end of the arc, I diameter, J start point)

/now enter the rest corners and set the motion back to linear

G01 **X**85 (G01 for linear traverse, X and Y in individual line because they are individual movement)

Y15

X15

/move away from the part, change tool to drill

T2 M06 (T2 to select to second tool to drill, M6 the change the previous one)

/move to location of drill

G00 **X**30 **Y**30 **Z**2 (G00 fast traverse reposition new location)

/ order to drill in multiple position and add coolant

G81 **Z**-15 **R**1 M03 M08 (G81 use to drill,R1 start plane for basic drilling,M03 for specifying the direction and M08 to turn the coolant on)

/move to new position

Y70

X70

Y30

/end the drill

G80 (G80 to end the drill)

Z50 (order to move away from the part-mill work piece)

M30 (use to end the program)

APPENDEX B

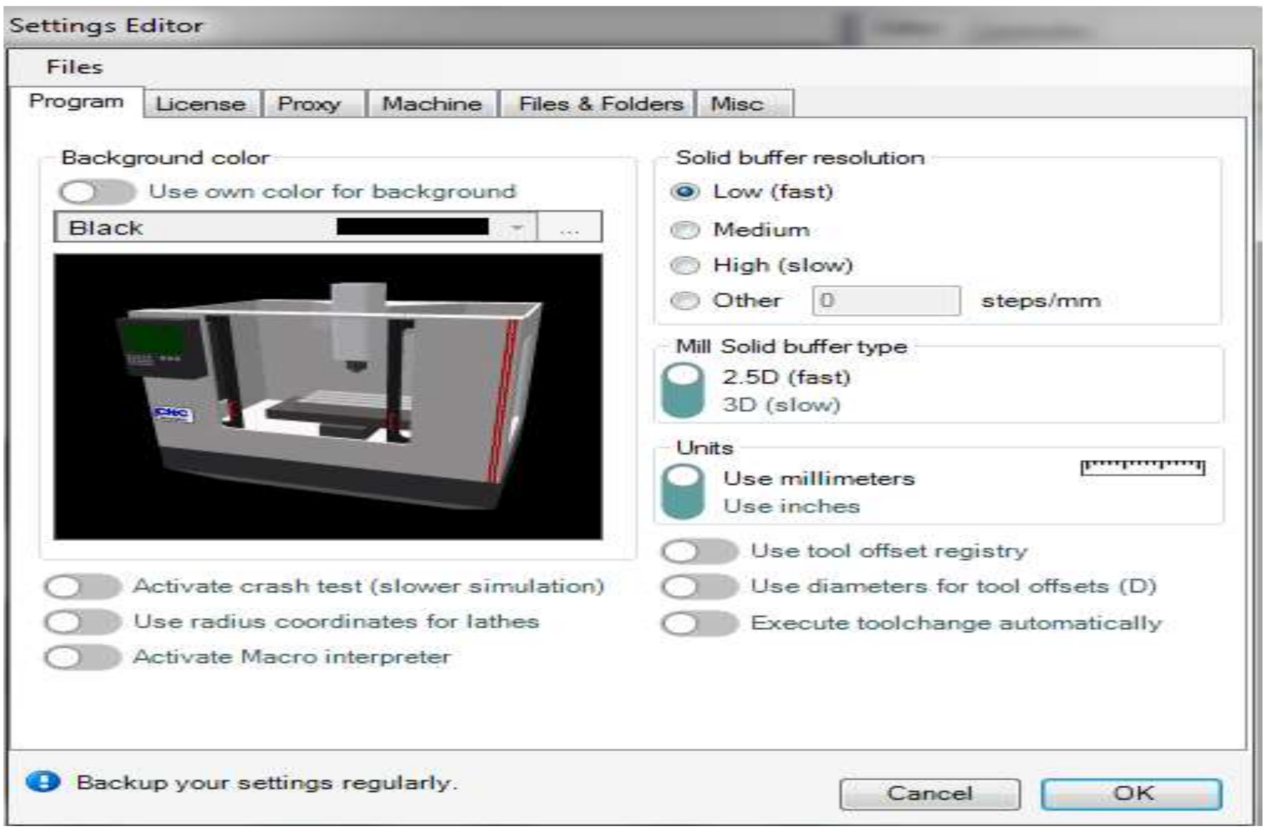

Fig.4.16: Selecting the machine and the unit millimeters

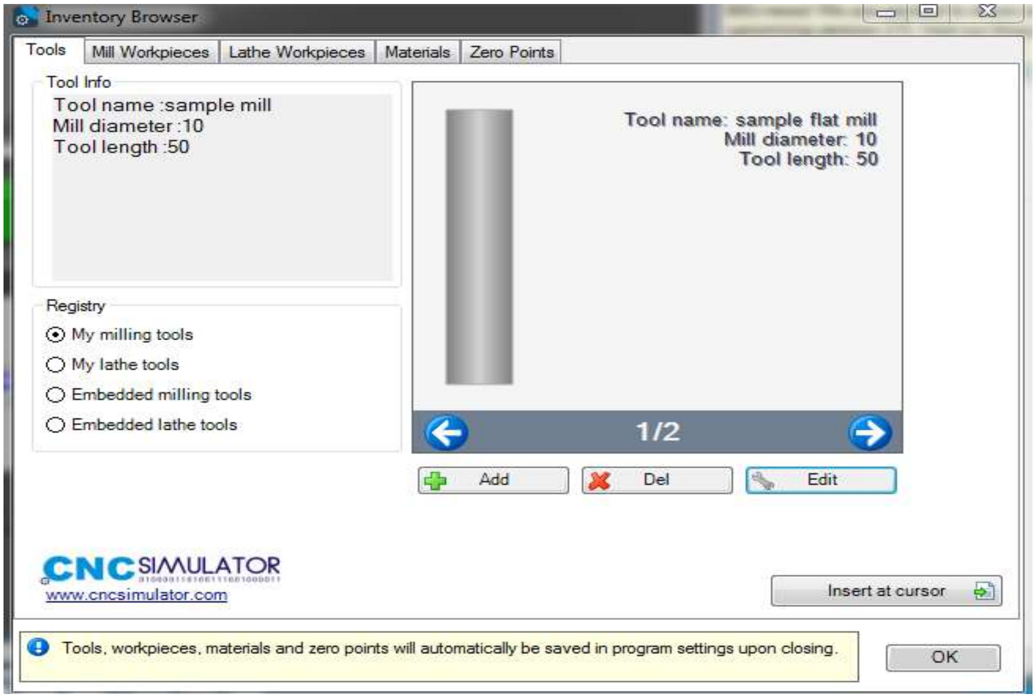

Fig.4.17: Selecting the sample flat mill with diameter 10 and length 50.

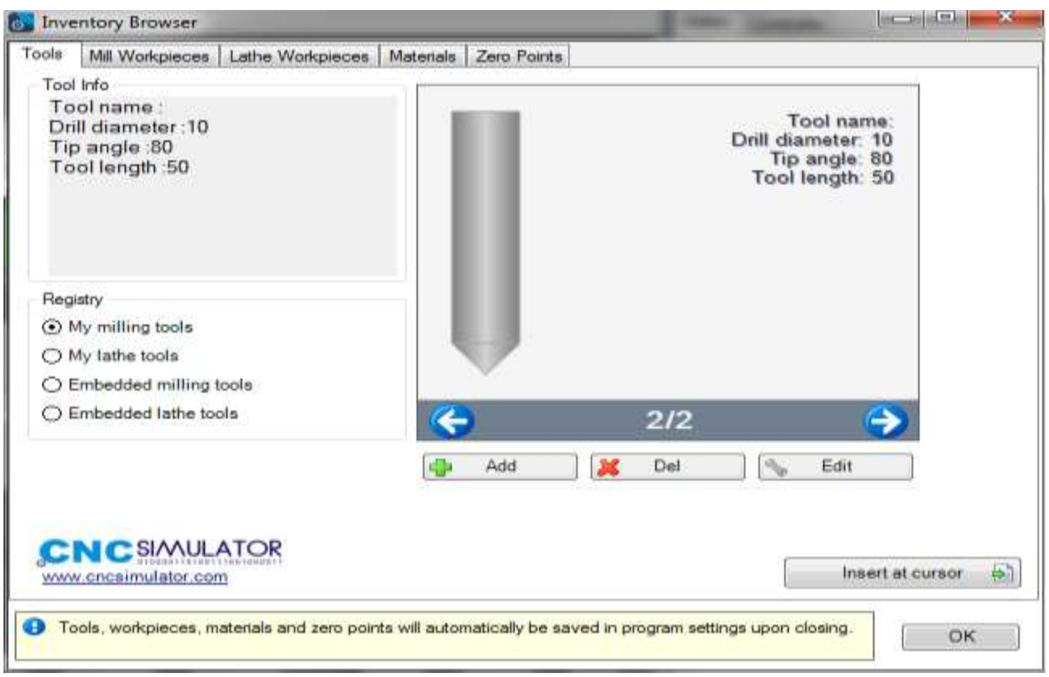

Fig.4.18: Selecting the sample pointed drill with diameter 10, length 50 and tip angle 80

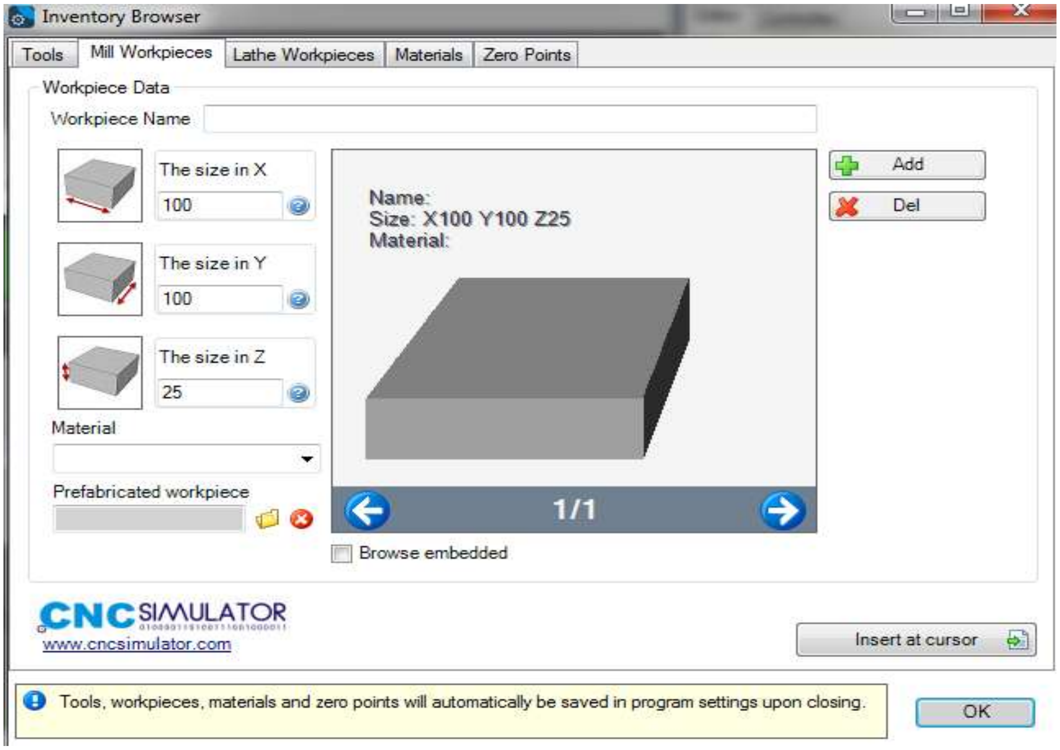

Fig.4.19: Selecting the mill work-piece with x 100, Y 100 and Z 25

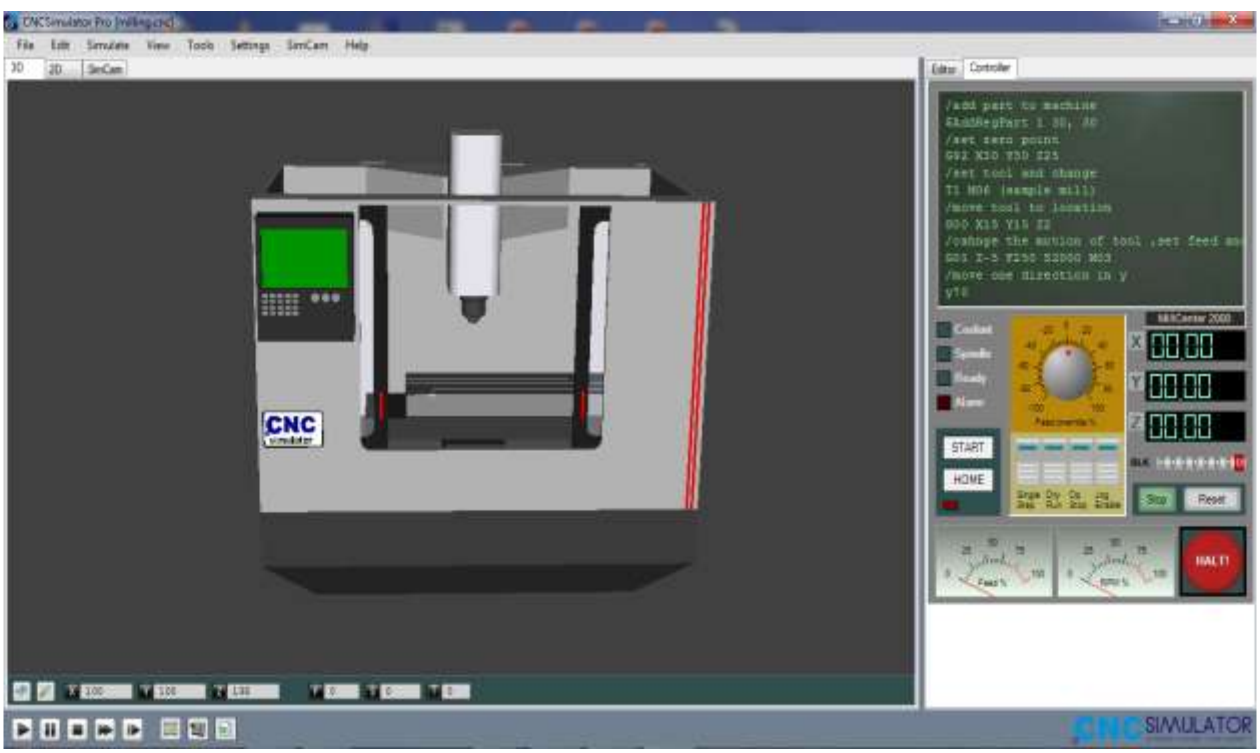

Fig.4.20: General view of the simulator

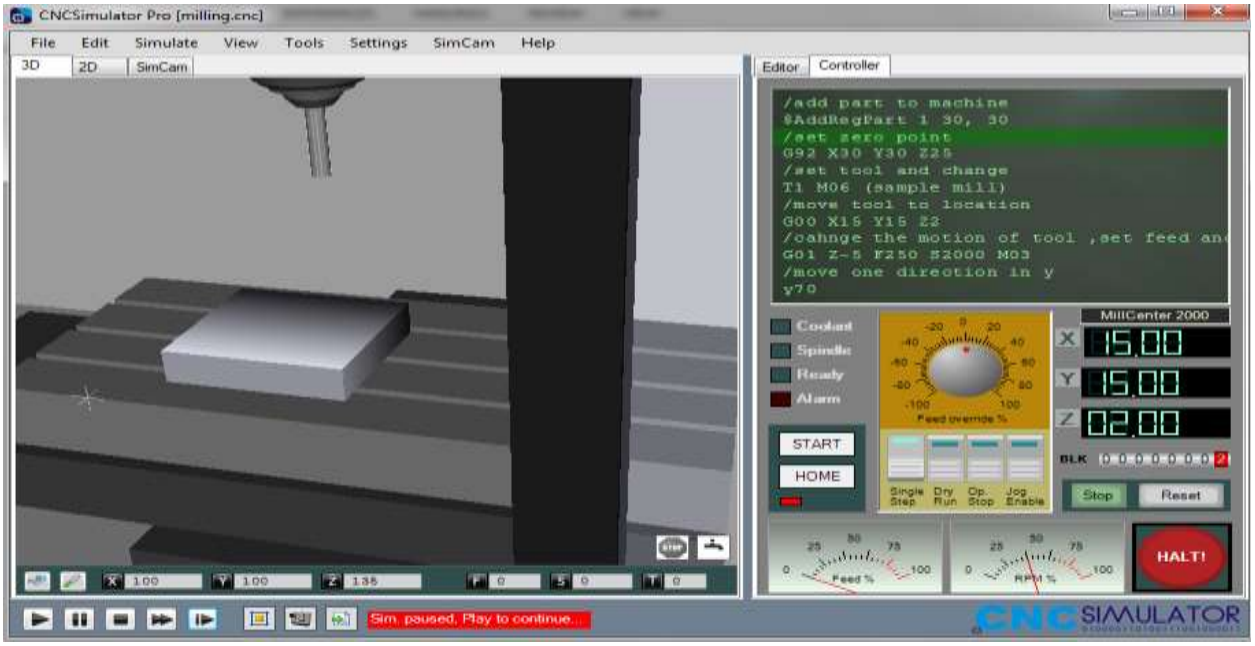

Fig.4.21: Add the mill work-piece to the machine

($addRegPart 1 30 30)

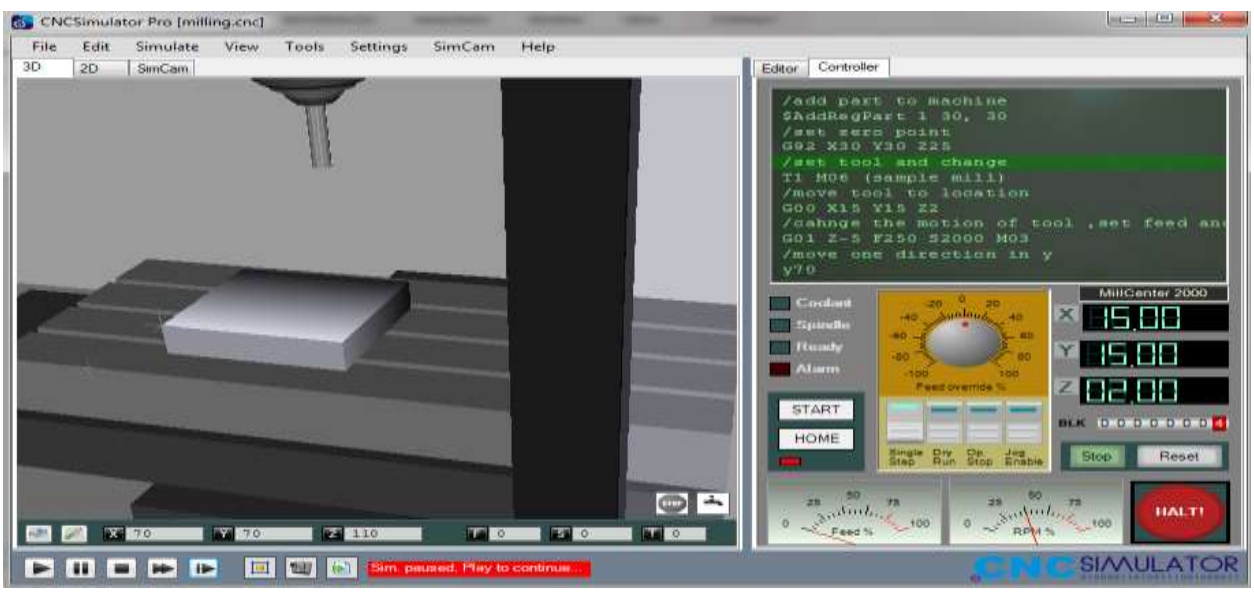

Fig.4.22: Setting the zero point (reference point)

(G92 X30 Y30 Z25)

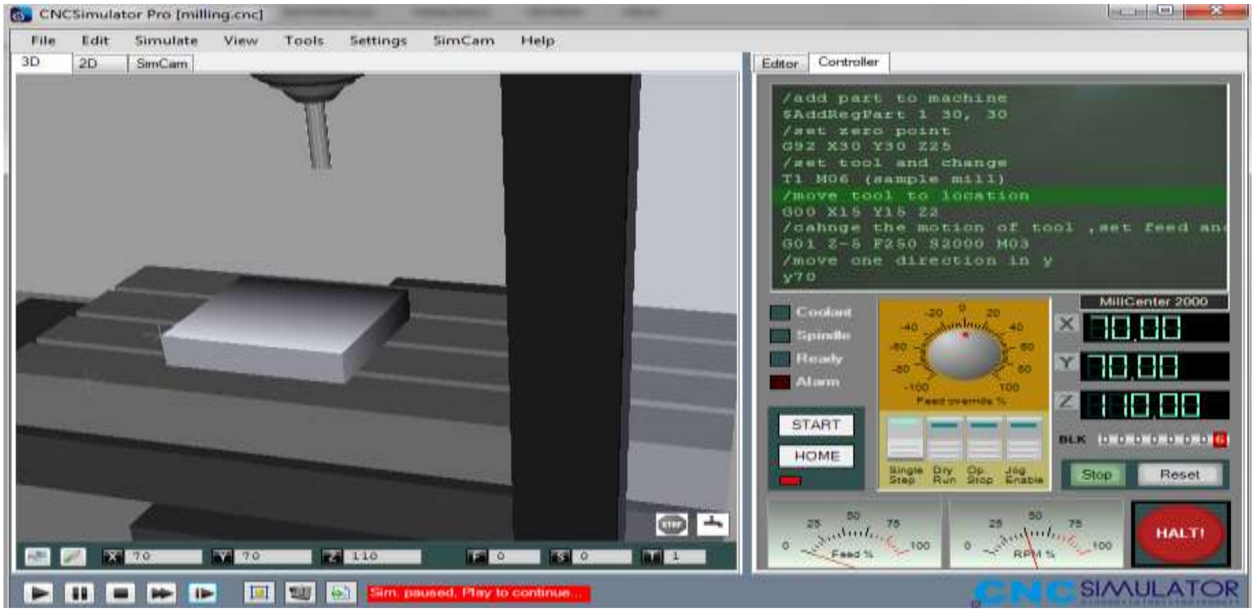

Fig.4.23: Loading the tool No: 1 sample flat mill by changing the previous one.

(T1 M06)

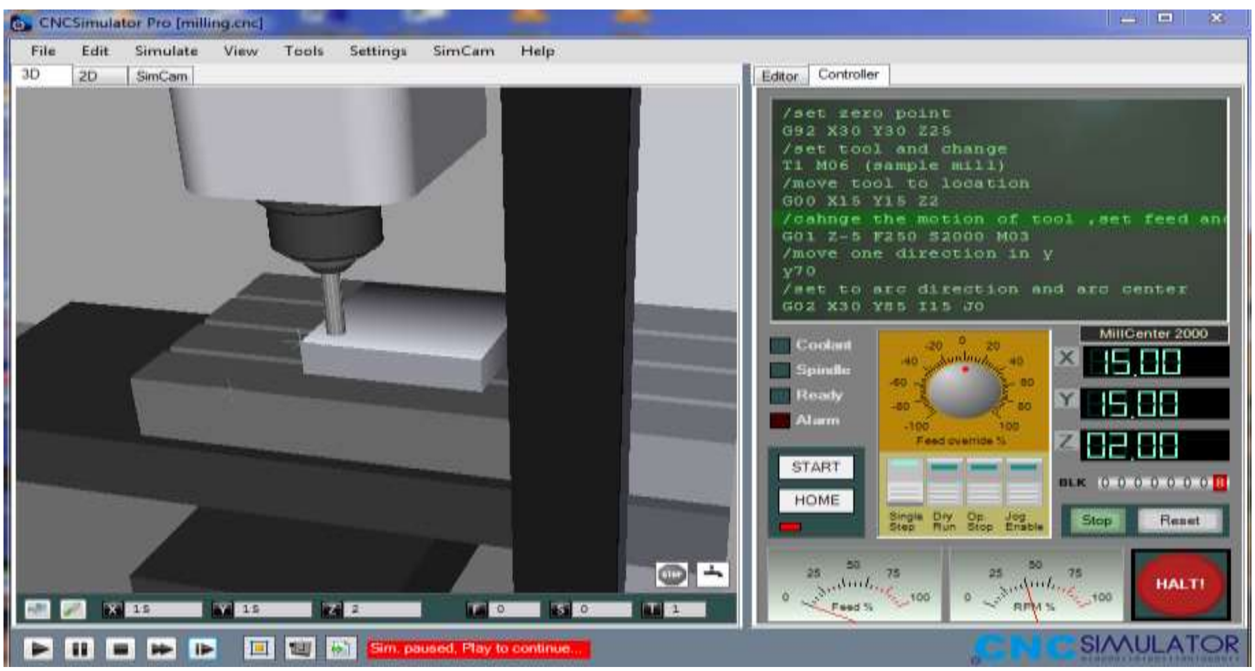

Fig.4.24: Moving the flat mill to location where to work start

(G00 X15 Y15 Z2)

Fig.4.25: Changing the motion of the tool and setting the feed and spindle

(G01 Z-5 F250 S2000 M03)

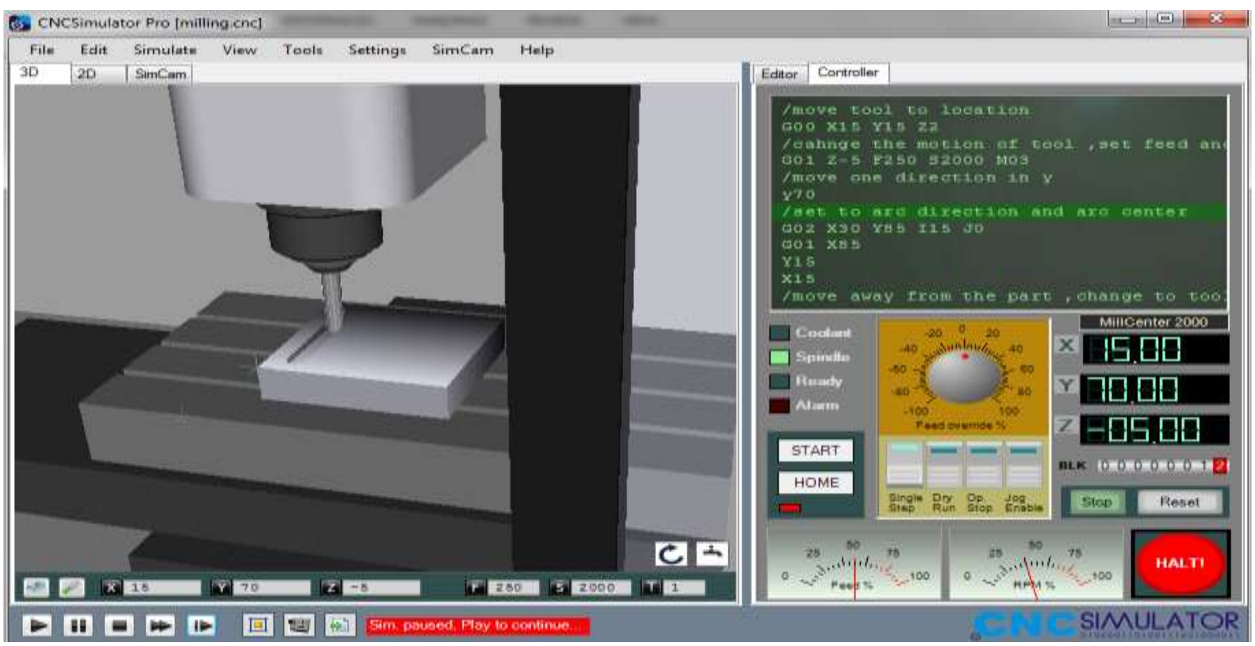

Fig.4.26: Moving the flat mill in Y axis

(Y 70)

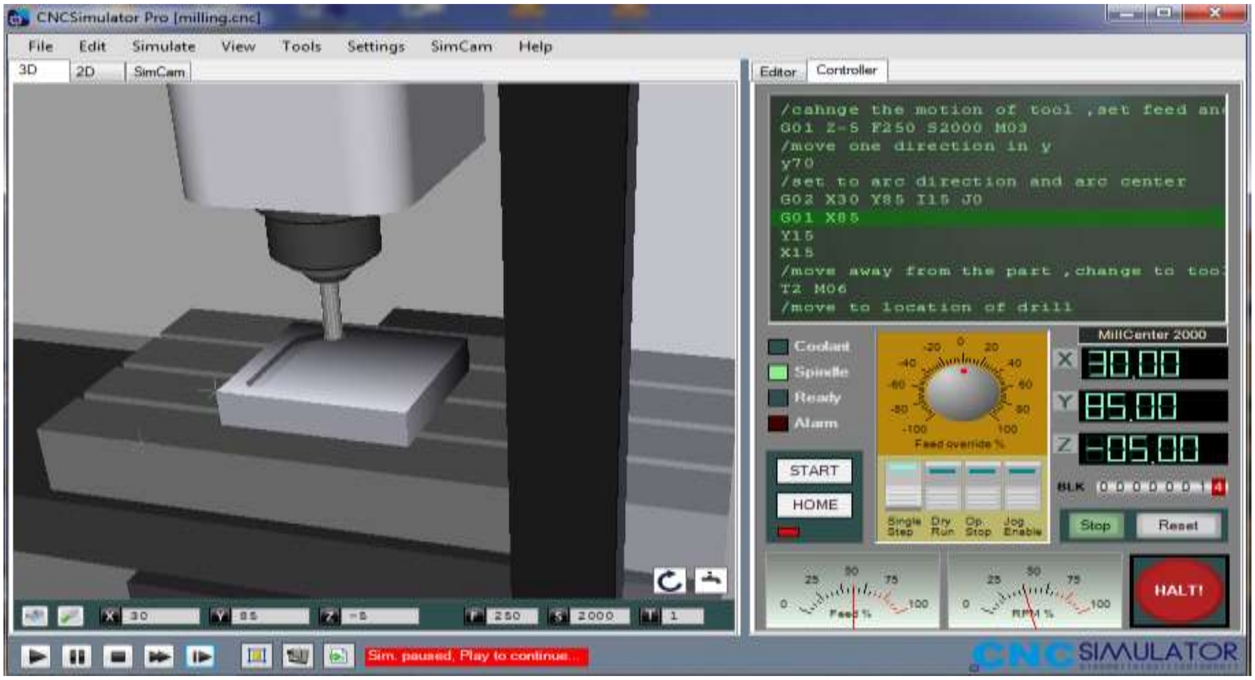

Fig.4.27: Achieving the Arc with specifying its end and center

(G02 X30 Y85 I15 J0)

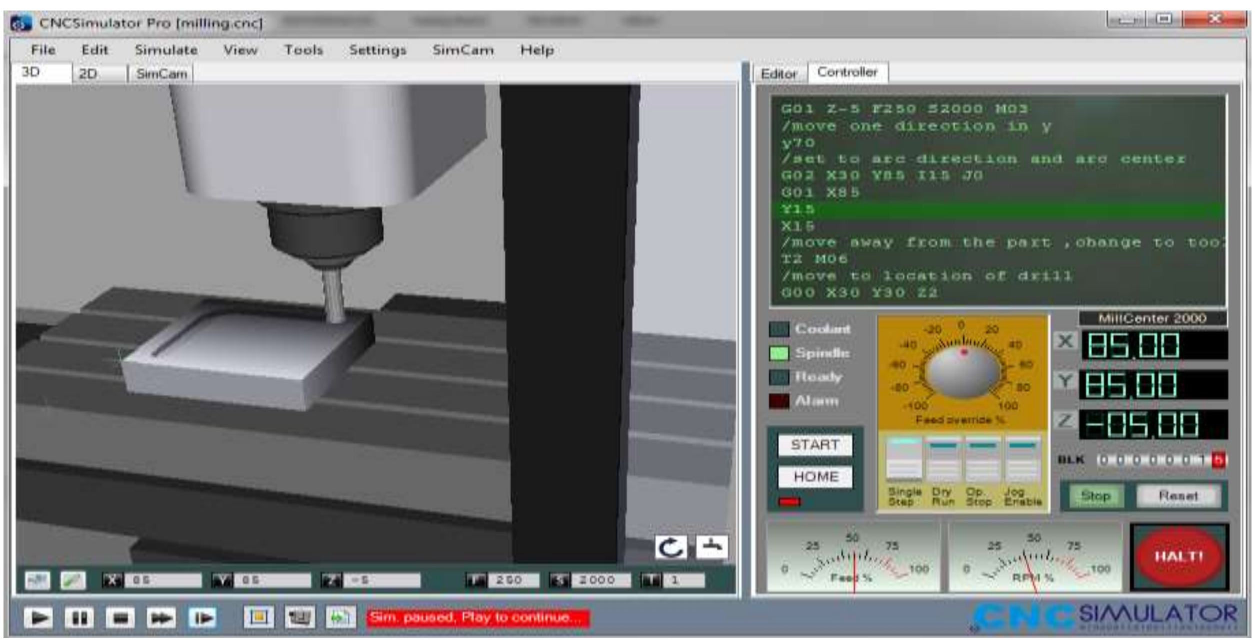

Fig.4.28: Moving in X axis

(G01 X85)

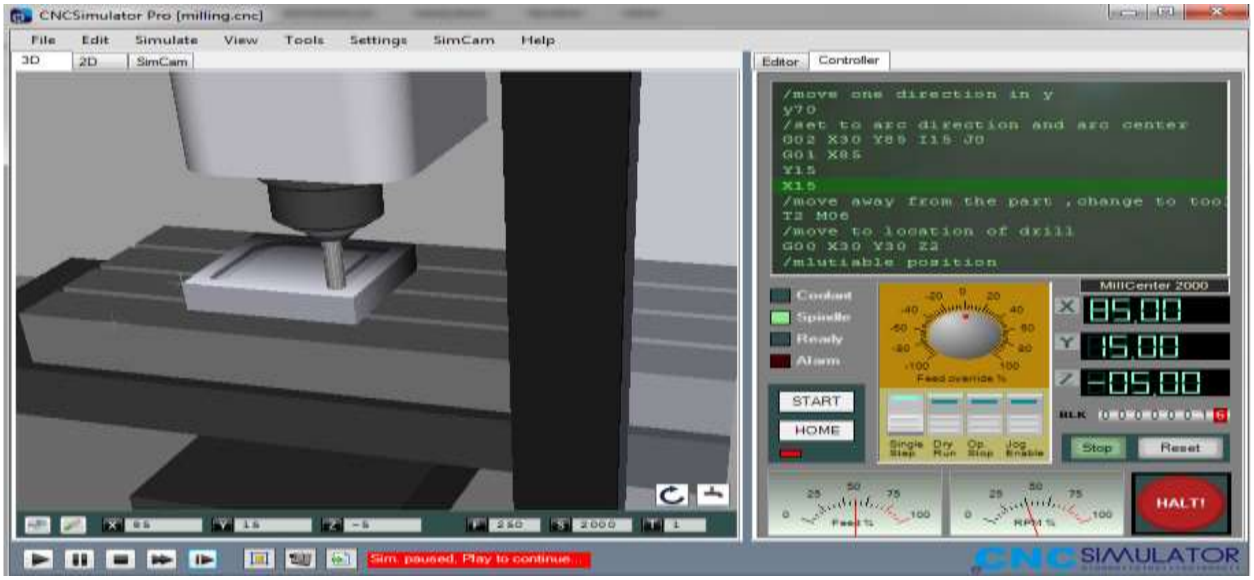

Fig.4.29: Moving in Y axis

(Y15)

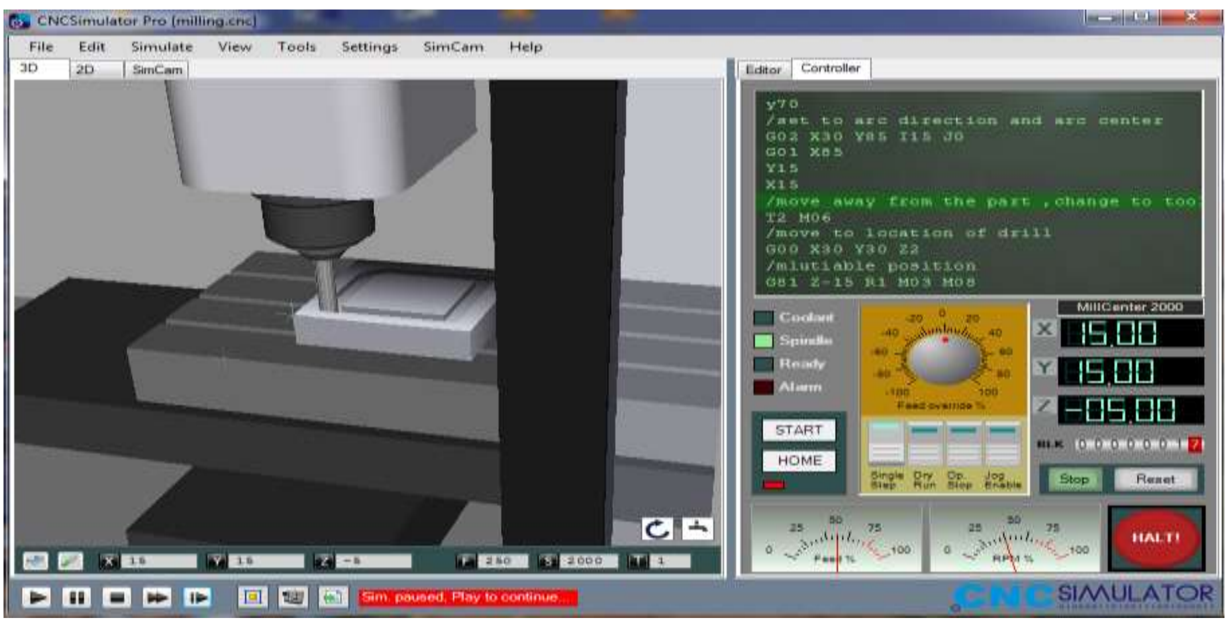

Fig.4.30: Moving in X axis

(X15)

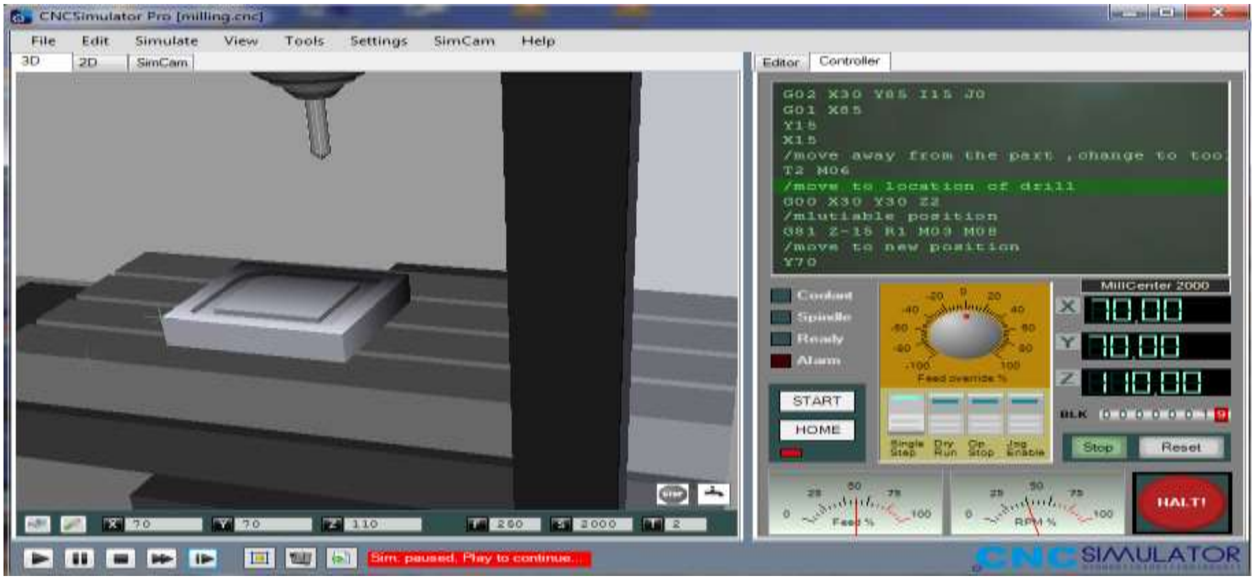

Fig.4.31: Moving the sample flat mill away from the part and changing the tool to sample pointed drill

(T2 M06)

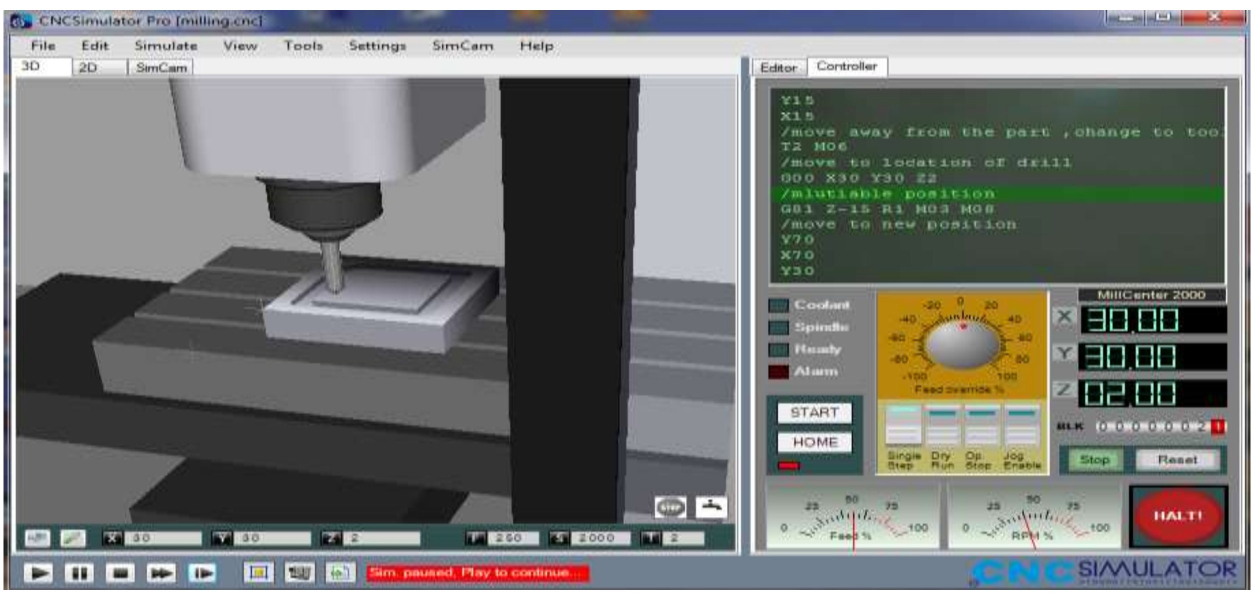

Fig.4.32: Located the drill tool to achieve the hole No 1

(G00 X30 Y30 Z2)

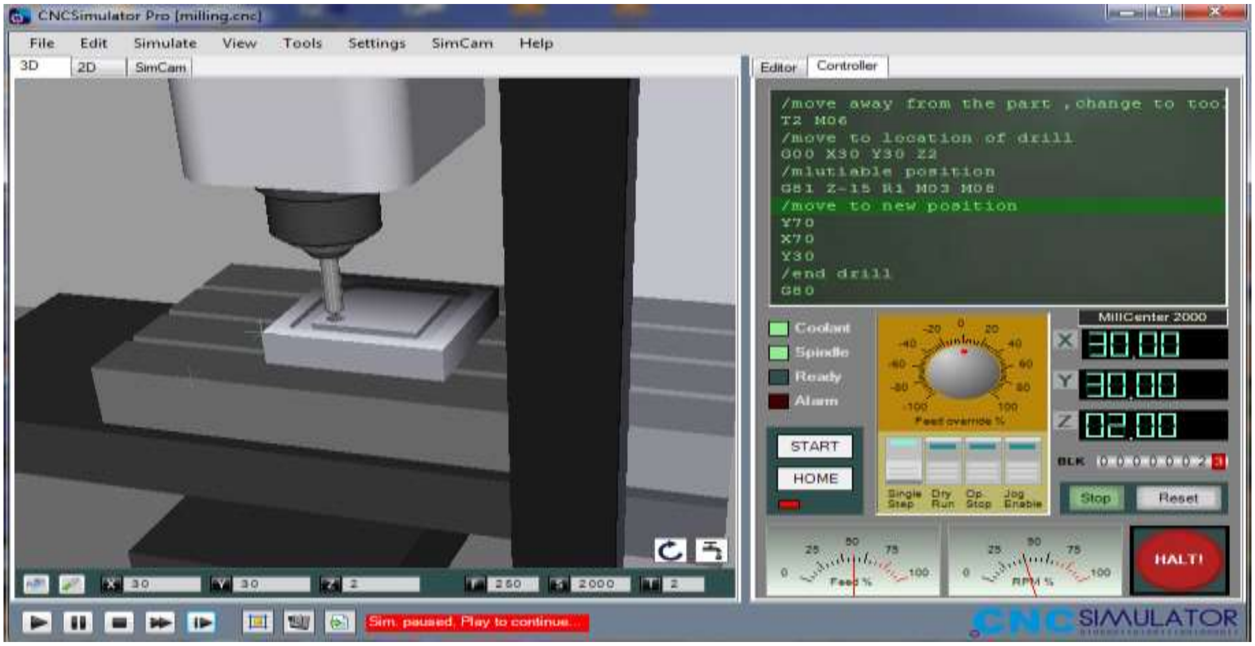

Fig.4.33: Achieving the hole No: 1

(G81 Z-15 R1 M03 M08)

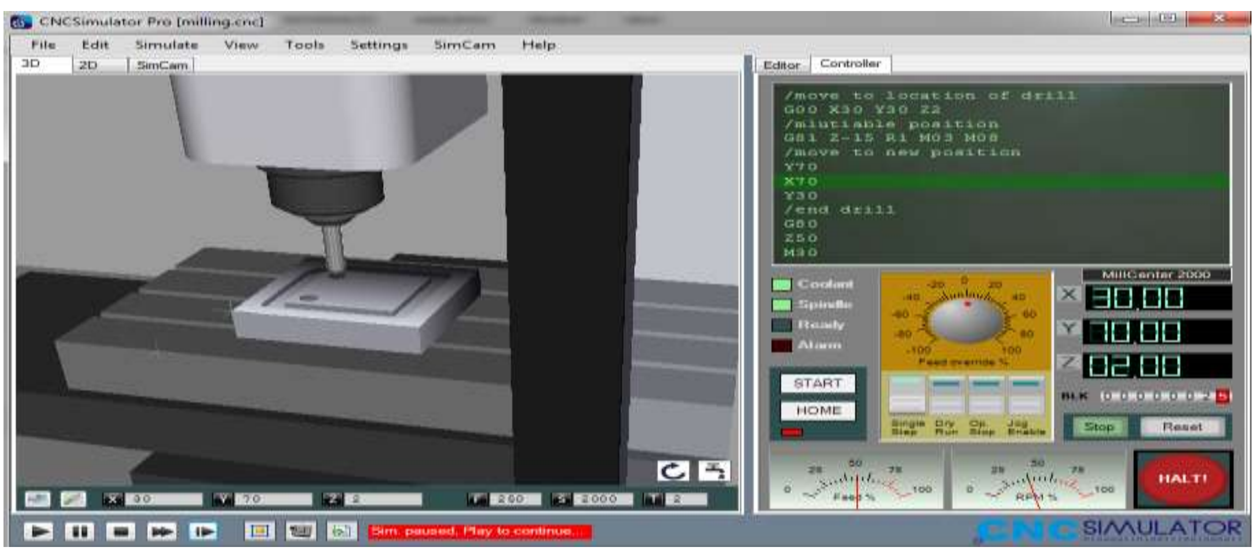

Fig.4.34: Achieving the hole No: 2

(Y70)

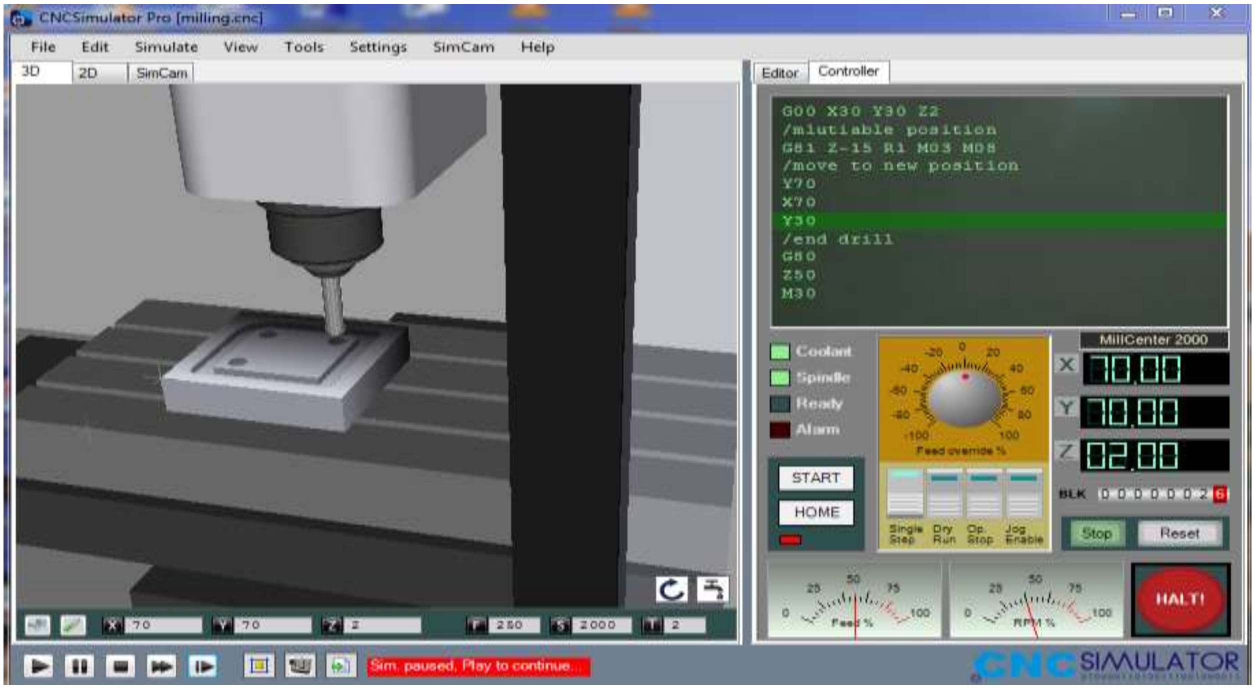

Fig.4.35: Achieving the hole No: 3

(X70)

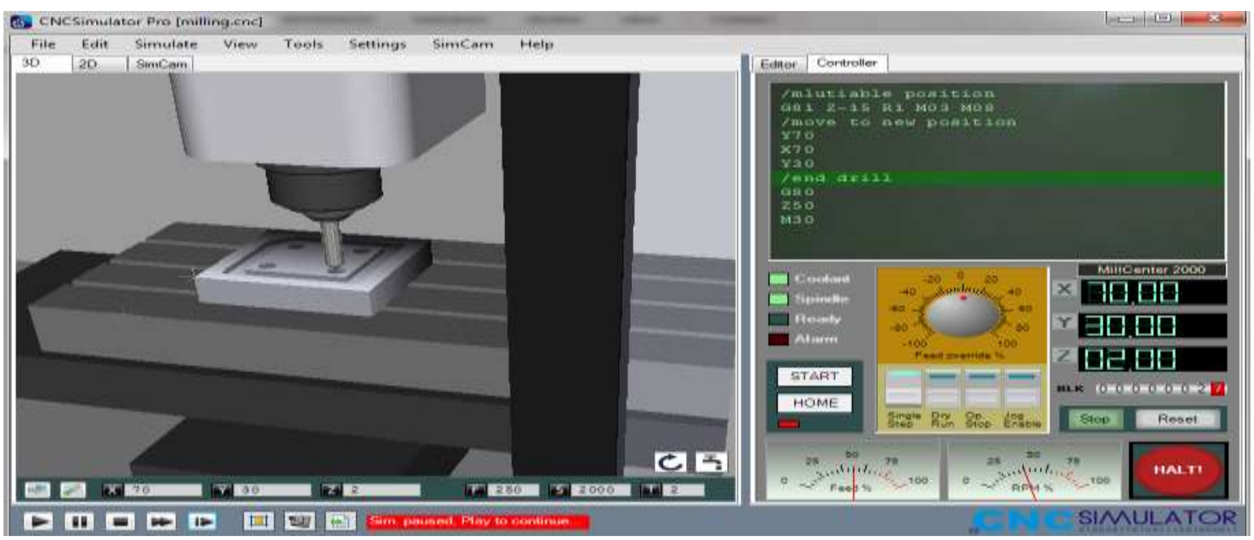

Fig.4.36: Achieving the hole No: 4

(Y30)

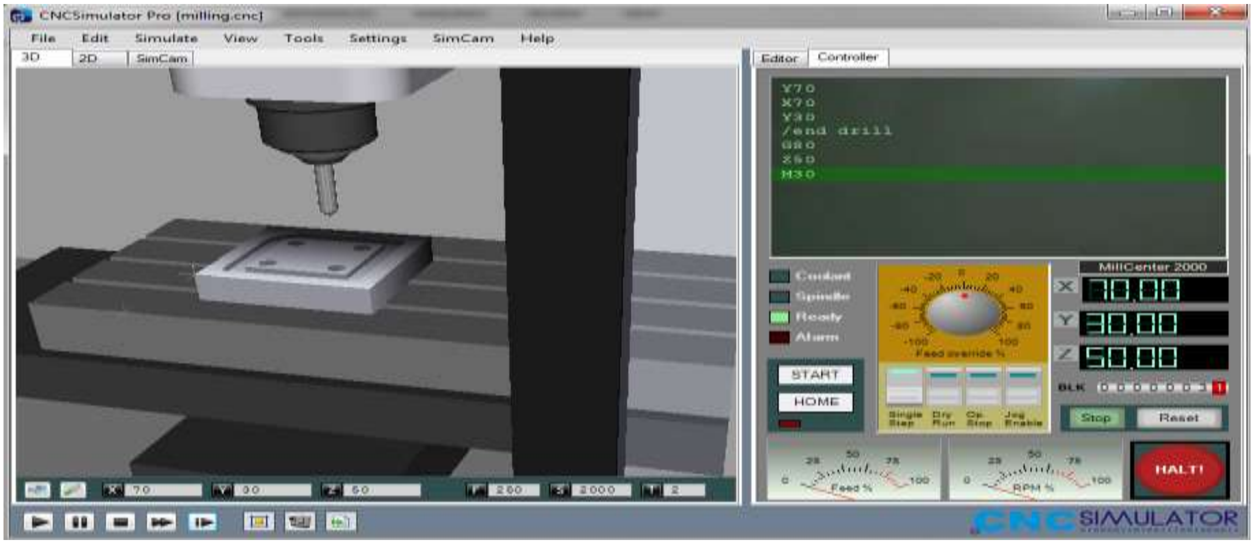

Fig.4.37: Moving the drill tool away from the part and end the program

(G80

Z50

M30)